Institute for Creation Research

GRAND CANYON

FIELD STUDY TOUR GUIDEBOOK

APRIL 9-16, 1988

Raft Trip on Colorado River
Bus Tour of Northern Arizona & Southern Utah
Hiking Groups on Grand Canyon Trails

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THE GRANDEST OF CANYONS

by John D. Morris

As you stand on the rim and peer down into the Grand Canyon as part of the ICR Grand Canyon Adventure, you are embarking on an activity experienced by few others, for on these adventures, an attempt will be made to attach a proper interpretation and a full significance to the data and the experience.

The Setting

Perhaps there is no sight on earth which matches the Grand Canyon. There are other canyons, other mountains and other rivers, but this canyon excels all in scenic grandeur. The ornate sculpture work, the wealth of color and the sheer size and majesty engulf the intruder, surpassing his ability to take it in.

The spectacle stretches 217 miles, not counting the 60 miles of Marble Gorge northeast of the canyon. It ranges in depth from 3,000 to 6,000 feet, and from 4 to 18 miles in width. The north rim, somewhat higher than the south rim, reaches an altitude of 8,500 feet, while the Colorado River cascades along at about 2,400 feet.

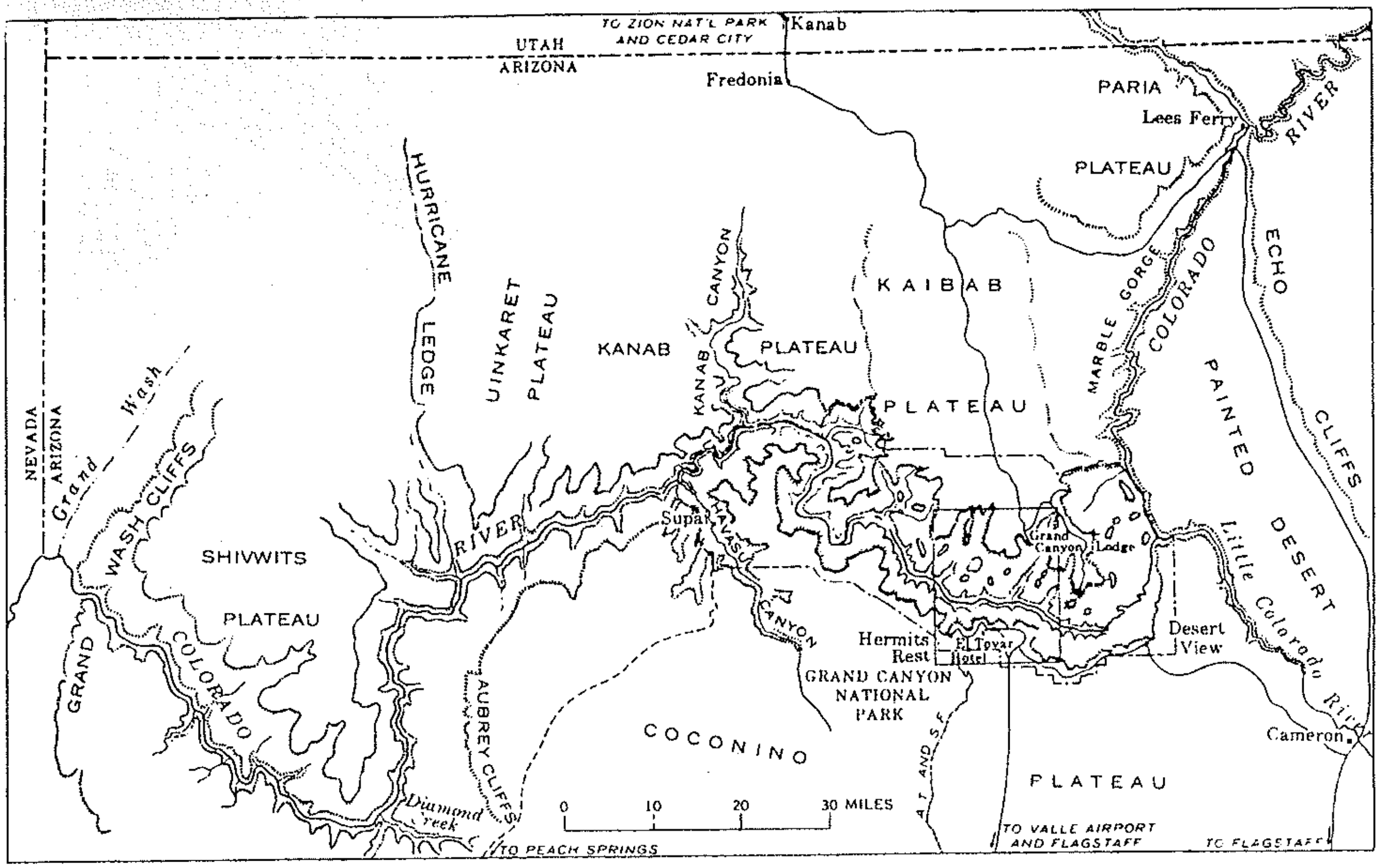
Within the chasm walls is a host of peaks and buttes, canyons within canyons and precipitous gorges and ravines. The most spectacular spires have been dubbed "temples," some towering a mile above the river. The scarcity of vegetation allows the eyes to feast on delicate hues which come alive as the sun strikes the walls.

Surrounding the Grand Canyon, throughout Northern Arizona, New Mexico and Southern Utah, are spectacles made up of the same rock units found in the canyon, as well as others which previously covered this area, now eroded away. A unique series of geologic events allows us to behold these various records of the past. We will all observe these on the ride from Phoenix to the Canyon, while participants on the bus tour will see much more, complete with explanations of how the various layers fit into true, Biblical history.

The Christian can appreciate, as no one else, the wonders and beauty of God's creation. He has given us the Grand Canyon and its environs as object lessons of His majestic power. Let us not fail to return to Him the praise, honor and glory due Him for His wondrous works.

The History

The single most striking observation one makes of the Grand Canyon is of the nearly horizontal layering of the many rock units. However, there are rocks, particularly deep in the inner gorge, which are quite different, and have an entirely different mode of origin. We plan to study and differentiate between rocks which were formed during creation week, rocks which were altered or deposited during Noah's Flood, and those which date from post-Flood days. Likewise, we plan to study effects of faulting and erosion which took place during Noah's Flood and afterwards.



SKETCH MAP SHOWING THE ENTIRE EXTENT OF THE GRAND CANYON

The Grand Canyon is about 217 miles long, not counting Marble Gorge upstream on the Colorado River. The depth of the Canyon varies between 3,000 and 6,000 feet, and the width from rim to rim between 4 and 18 miles. In the Bright Angel area (shown as a box on map) the South Rim has an elevation of approximately 7,000 feet, the North Rim an elevation of 8,000 feet, and the Colorado River about 2,400 feet. The Coconino Plateau is on the south of the Grand Canyon, and the Kaibab Plateau is on the north. Note that the Grand Canyon and Marble Gorge isolate virtually the entire northwestern corner of Arizona from the rest of the state.

In order to do this, we must be able to understand the historical interpretation conventionally attached to the features of the Grand Canyon and be able to refute it. Where necessary, this guidebook is designed to provide you with enough information to do just that, and to stimulate your thinking as we, together, attempt to construct a more accurate model which fits the data better. Please keep the guidebook handy. The wealth of information and maps is your key to full enjoyment of your trip. We can be sure the creationist understanding of earth history is far more scientifically and personally satisfying than the evolutionary one. The Bible records accurate history, and so do the rocks in the Grand Canyon.

The People

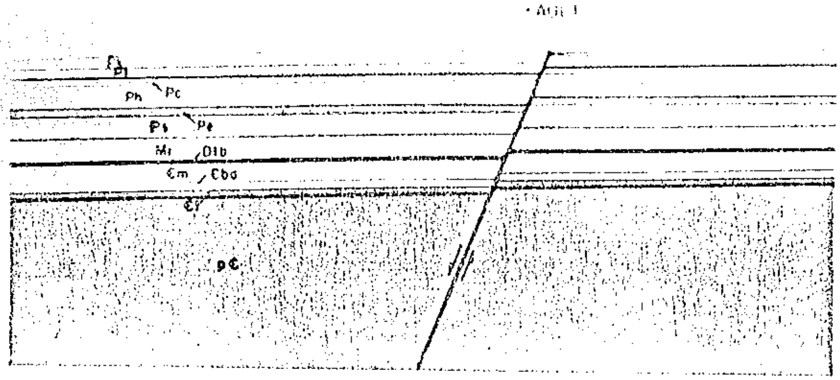
The most important part of any adventure such as this is the people, and as far as we know each adventure consists of Christians who desire to know God more fully through His creation and increase their effectiveness in service for Him. The fellowship will certainly enrich us all, particularly as we gather for group devotions each day. The primary goals of the trip are, that, because of our study and mutual encouragement we will be more like Jesus Christ in actions and attitudes, more able to assist those who struggle with issues of creationism, and better equipped to lead others into a relationship with the One who made such fellowship possible.

The Grand Canyon provides ample opportunity to reflect on such matters, for the layers of beauty on all sides are, in actuality, the grim reminder of sin, judgment and destruction. Peter tells us that "the world that then was, being overflowed with water, perished" (II Peter 3:6). All that remains of the pre-Flood world is rock laid down by Flood waters, and fossils encased in these rocks--inhabitants of a world so sinful that it had to be destroyed.

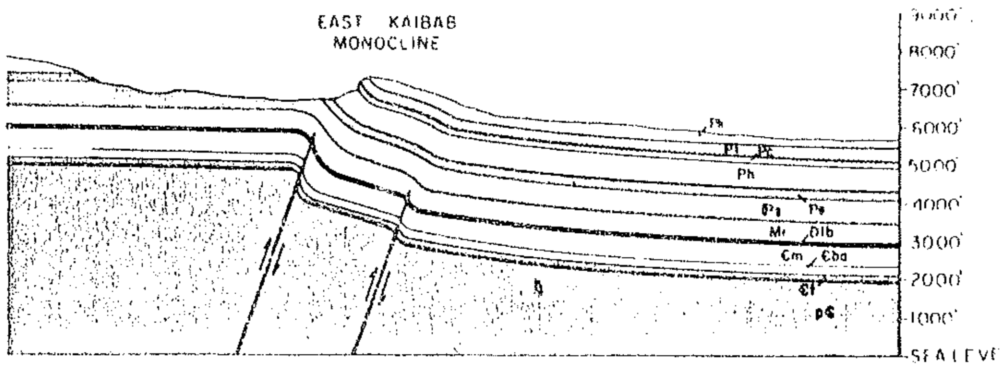
On the other hand, we are assured that the world will be restored to its former glory one day; the effects of sin and judgment wiped out. The Bible describes the coming age in glorious terms, and God has left us a few additional clues in the Grand Canyon, the destroyed remnant of the former world. Imagine how majestic and grand the world must have been for its destruction to exhibit such majesty and grandeur, and ponder the surpassing glory of the coming new earth.

The true gospel of Jesus Christ includes far more than His marvelous redemptive work, although that is the focal point of all history. The complete "good news" rightly includes the entire person and work of Jesus Christ, starting with His work of creation and culminating in His final vanquishing of all sin and reigning over the creation made perfect once again. On this study tour, let us not only ponder His works of judgment and salvation at the time of Noah's Flood, let us more fully grasp the complete work of our Creator, Savior and King, our Lord Christ Jesus.

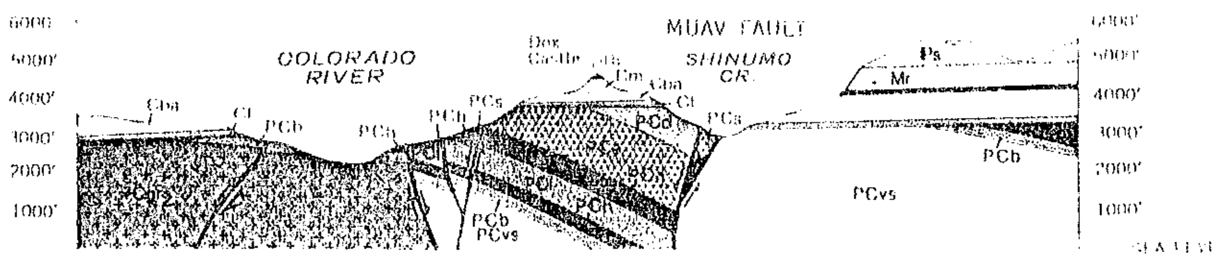
ROCK STRUCTURES OF THE GRAND CANYON



Shown above is a cross-sectional diagram of a fault, a surface within the earth along which movement of adjacent rocks has occurred. The Grand Canyon rocks in many areas show the mismatch of strata which is one of the best evidences that a fault exists.

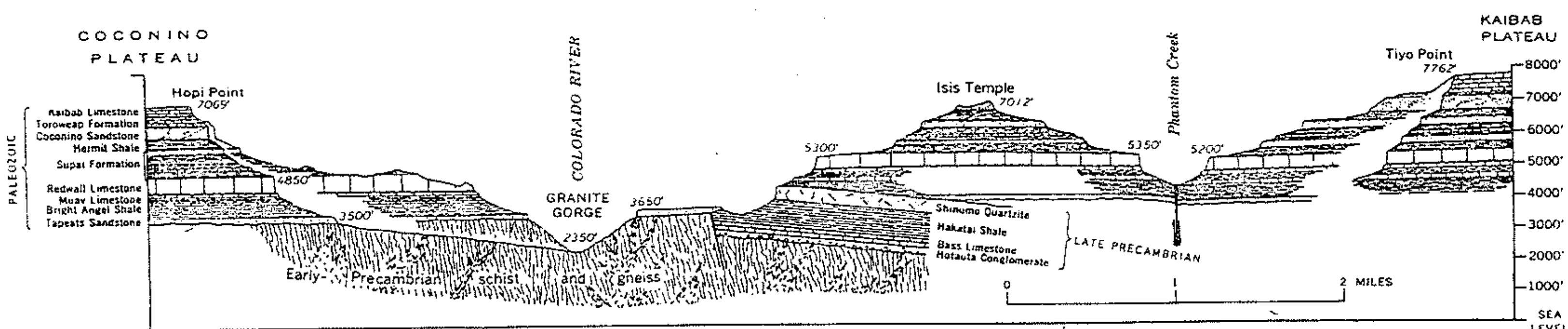


Shown above is a monocline, a fold structure in which the strata flex only in one direction from the horizontal. Strata of the Kaibab and Coconino Plateaus were uplifted 2000 feet above surrounding areas by monoclines on the east and west of the Grand Canyon. An anticline is a fold structure in which strata flex in two directions dipping away from the fold. A syncline is a fold structure in which strata flex in two directions dipping toward the fold.



Shown above in cross-sectional diagram is an unconformity, a surface of erosion or nondeposition which is buried within the earth. Note that the Tapeats Sandstone (abbreviated "Ct" on the diagram) overlies various rocks including tilted and eroded stratified Precambrian rocks. Directly below the Tapeats Sandstone is what geologists call the "Great Unconformity." It may represent the division between pre-Flood rocks below and Flood strata above. Note complex faulting which has changed the elevation of the unconformity.

6!
3000 limestone lies below.



Cross section of Grand Canyon from Hopi Point, on the south rim, to Tiyo Point, on the north rim.

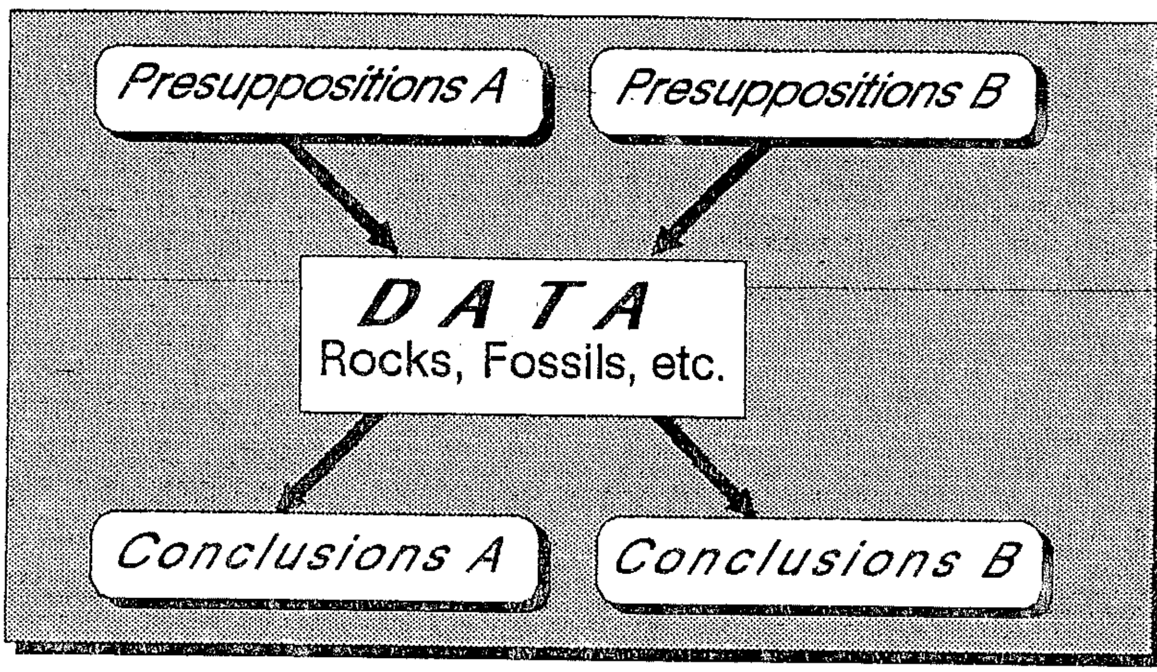
This section shows the strata of rock into which the canyon is hewn and the alternating cliffs and terraces to which they give rise. It is drawn strictly to scale—that is, without vertical exaggeration—and therefore shows the actual proportions of depth to width. The Grand Canyon here has a depth of about 1 mile and a width from rim to rim of 7½ miles.

This page was not in the 88' 1988 Guidebook.

FIVE FOUNDATIONAL CONCEPTS IN GEOLOGY

I. The Importance of Presuppositions in Interpreting Geologic Data

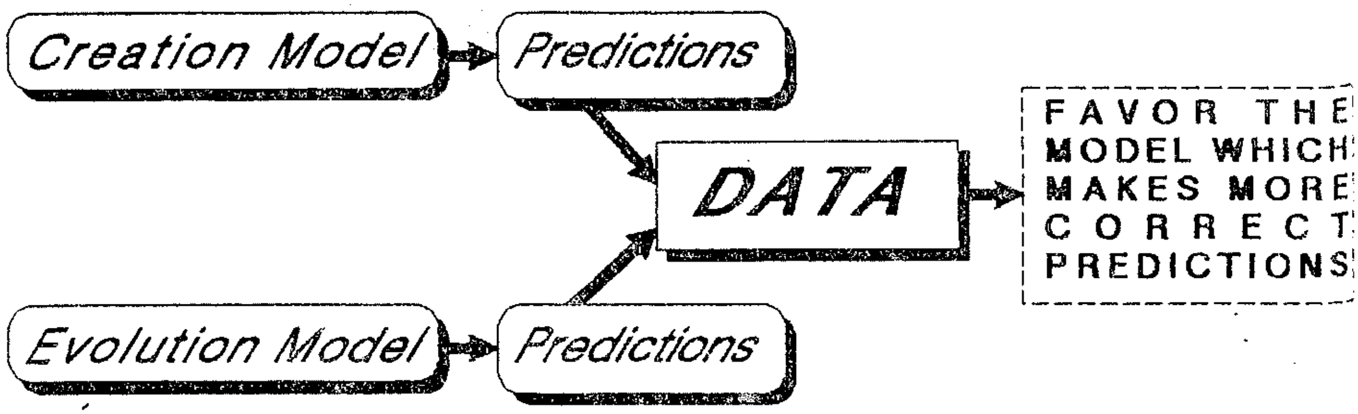
All scientific data, particularly that which records the unobserved past, must be interpreted in light of certain presuppositions, or bias, which may or may not be recognized. Geologic data have been interpreted within both evolutionary-uniformitarian and creationist-catastrophist models with varying degrees of success. Deluge geologists recognize their bias and are convinced that the geologic data fit their model better than the evolutionary-uniformitarian model. Unfortunately, few traditional geologists are aware of their own bias, and assume long ages of evolutionary development before looking at the data. Remember, rocks and fossils don't talk. They must be interpreted.



II. The Means of Evaluating the Effectiveness of Models

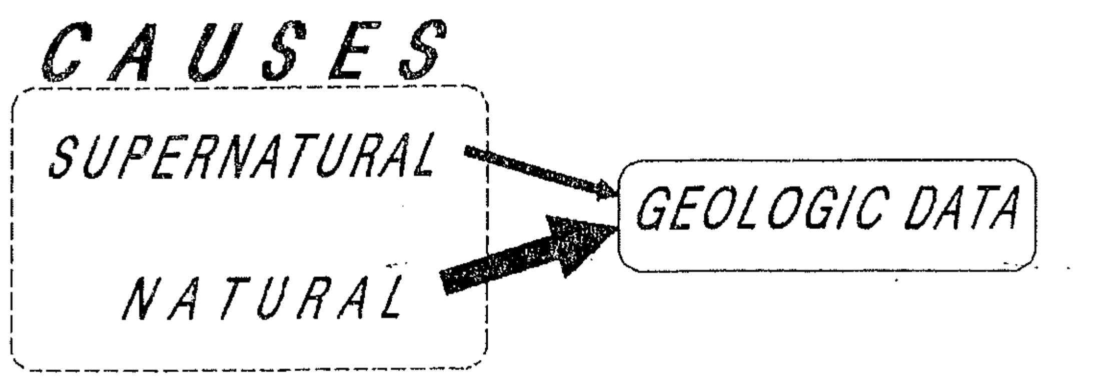
Models of earth history which more effectively predict the character of present geologic data with fewer secondary modifications to the basic model are to be preferred by geologists. No model of the unobserved past is "scientifically" provable, but the effectiveness of their predictions can be compared. The one which provides the better fit to the data is more likely correct. Consider the fossil record as an example.

Fact: Fossil types appear abruptly, fully formed, easily classified into taxonomic groups without transitional forms. The creation model predicts this, insisting that basic plant and animal types have existed since creation. On the other hand, the evolution model, which predicts that transitional forms must have lived in the past, must be modified to explain the data. Usually evolutionists say that a small, isolated group of animals evolved rapidly to a higher stable type, leaving no transitional fossils. Others still hope that transitional forms will some day be found. The creation model has greater explanatory power with respect to the fossil record, since it needs no secondary modifications to handle the data.



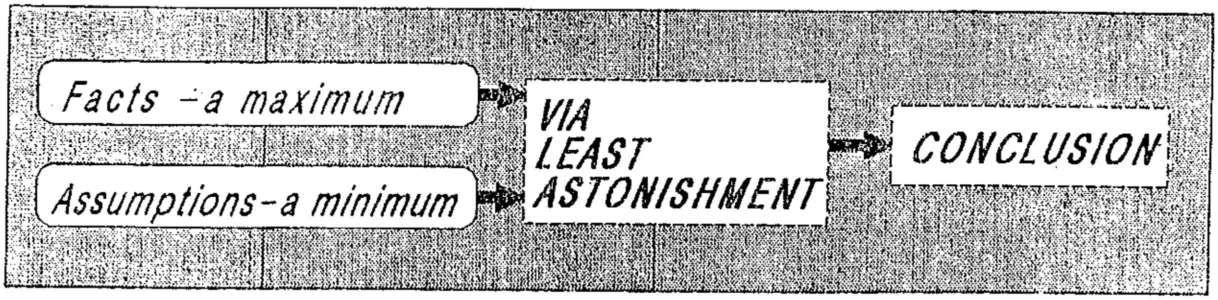
III. <u>The Principle of Economy of Causes</u>

Geologists should prefer interpretations of past geologic events which are in accord with the laws of physics and chemistry, and shun those which are statistically improbable. Supernatural causes should be invoked only when the evidence, carefully considered, dictates, or where the statements of Scripture specify. God's work of creation was completed at the end of six days, after which the earth's systems were to run in accordance with the natural laws He established. Although He has chosen to act outside those laws on specific occasion, the geologist must in all other cases attempt to explain data within the framework of existing natural law and God's providential sustenance.



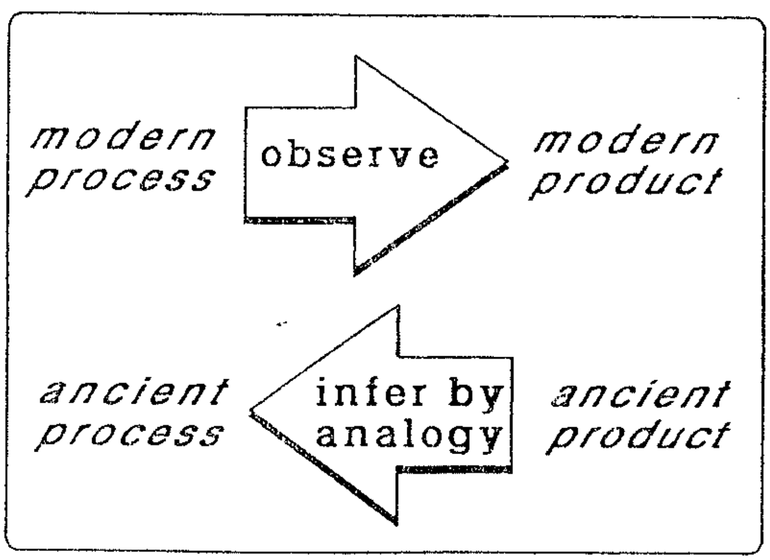
IV. The Principle of Least Astonishment

Geologists should prefer interpretations of ancient geologic events which explain the greatest number of facts with the fewest assumptions. In short, the simpler, more straitforward, intuitive interpretation is preferred over the complex interpretation, all things being equal. For example, crossbedding in sandstone is usually considered to be a result of moving water depositing sand grains on an irregular surface. Others consider the features to be due to crystalline rock fracture as pressure is released by overburden removal. The sedimentary origin clearly requires fewer assumptions and handles more data as well.



V. The Principle of the Process/Product Analogy

Geologists should prefer explanations of the origin of geologic products which accord with geologic processes which they know or can infer to have occurred, without making the unlikely assumption that such processes have always acted at the same rate, scale or intensity as at present. Observed geologic process (including local catastrophes such as the eruption of Mount St. Helens) produce geologic products similar to, although usually of lesser extent than, geologic products of past processes. By analogy we can infer the type, rate, scale and intensity of the processes responsible for products in the geologic record.



SUMMARY OF THOUGHTS ON EROSION OF THE GRAND CANYON

by Steven A. Austin

Note: This short article is a plain English condensation of the more technical article "Erosion of the Grand Canyon--A Geologist's Personal Reflections" which appears immediately after this summary.

Twenty-five years ago I stood on the rim of the Grand Canyon contemplating the forces of erosion that had produced that awesome spectacle. Two observations came to my attention: First, I recognized that an enormous amount of material had been removed to create the 217-mile-long form of the canyon. (My simple calculation estimated just under one thousand cubic miles of strata had been excavated.) How was the material removed and where did it go?

Second, I noticed that the plateau through which the Grand Canyon occurs is much higher than the region on the west and east. Most interesting was the observation that the Colorado River is positioned flowing from east to west through the elevated plateau acting like a "river that flows uphill". Why did the Colorado River select its location through the more elevated area of northern Arizona, rather than around that plateau? Rivers, I know, like to take the easiest path.

As I contemplated the magnitude of Grand Canyon erosion and the improbability of the Colorado River being positioned where it is, I tried to devise an explanation consistent with evolutionary theories of geology which I had taught in school. I imagined that the ancestral Colorado River was located across northern Arizona as it is today, but that there was no elevated plateau. The whole area was low, I supposed, until uplight of the plateau caused the river to erode into the slowly rising land. That uplift I had been taught occurred from fifty to seventy million years ago. I concluded that the Grand Canyon was a long enduring feature which had evolved by the slow down cutting of the Colorado River.

The theory for the Grand Canyon I had favored was simple and elegant. It even conformed with evolutionary theory. It explained things in terms of processes that I know and observe. All I had to do was imagine how the slow rise of the land was balanced by continuous erosion by the ancestral Colorado River during periods of tens of millions of years.

The more I considered the theory that the Colorado River eroded the Grand Canyon, the more problems I had. Chief among these was the nagging question, "Where did all the sediment go?" To the west of the Grand Canyon there ought to be an enormous deposit of silt, sand and gravel deposited by the ancestral Colorado River. Not just one thousand cubic miles of eroded Grand Canyon strata, but an enormous quantity of sediment should be found from seventy million years of erosion of the entire drainage basin. My simple calculation showed that the muddy waters of the Colorado River now carry enough sediment to total one million cubic miles if erosion operated slowly over seventy million years. No colossal delta of silt, sand or gravel has been found! Instead, immediately west of the Grand Canyon occurs a thick limestone layer. where there ought to be silt, sand and gravel.

I began to entertain a notion that could be regarded as geologic heresy: the Colorado River did not erode the Grand Canyon! Soon I found comfort knowing that many other geologists also had dismissed the ancient ancestral river theory. For several years I tried to devise an alternate way to leave the plateau uplifted and uneroded for millions of years, then repositioning the Colorado River across it just recently. I imagined that a long, straight, and deep gully began to erode eastward from northwestern Arizona through the plateau and the present location of the Grand Canyon. The original Colorado River, I supposed, was diverted through the enormous gully. I freely admitted that I was attributing the Grand Canyon to one of the world's most unusual natural accidents. My mind could no longer continue to think that way.

As I evaluated the progress of my thinking on the Grand Canyon, I began to ask myself if I was laboring with a concept of geologic time which really did not exist. Could the Grand Canyon instead be the result of rapid erosion and the plateau in northern Arizona a young geologic feature? I was no longer thinking like an evolutionist and uniformitarian, but like a creationist and catastrophist. The concept I was entertaining resembled the account of Noah's Flood and the legend of the Havasupai Indians (who live in the Grand Canyon today and tell a story very similar to the Bible).

Lately, I've been ~~supposing~~ that (the plateau land in northern Arizona was uplifted rapidly) and that the drainage basin upstream was blocked by the plateau. That elevated plateau

...ed by that ... plateau would have formed a gigantic natural dam with a lake, east of the present Grand Canyon. Thin sedimentary deposits from the lake occur east of the canyon. Modern experience with man-made dams shows that when they fail, they fail catastrophically. I supposed that the northern Arizona dam also (failed rapidly) allowing the impounded lake to drain westward over the plateau causing significant erosion to the Grand Canyon.

A catastrophic drainage model for the origin of the Grand Canyon needs to be supported by geologic evidence. Several evidences suggest that the landscape is a relict feature, not forming slowly by modern agents of erosion. Many elements of northern Arizona appear to be stagnant landforms, left over from ancient water erosion on an immense scale. The plateau land around the Grand Canyon has a flat surface which appears to have been beveled by sheet flooding. The Grand Canyon, itself, has amphitheater-headed side canyons and a meandering course which resemble the system of canyons formed rapidly by breaching of a dam at Mount St. Helens by mudflows on March 19, 1982. Slopes of the canyon are usually covered with a red or brown coating of minerals which argue that its slopes are in an arrested stage of development, not continually evolving.

The Grand Canyon continues to astound and amaze. I have found that Scriptures, while they do not discuss the Grand Canyon specifically, do give an excellent model within which to interpret the data. Furthermore, the creation/catastrophe model provides more satisfying answers than the evolution/uniformity model.

EROSION OF THE GRAND CANYON--
A GEOLOGIST'S PERSONAL REFLECTIONS

by Steven A. Austin

Grand Canyon, the world's most awesome erosional wonder, captures my attention and causes me to contemplate the forces of nature which have excavated it. As I stand on the south rim I see only a fraction of its true dimension. The Grand Canyon is 217 miles long, not counting 60 miles of Marble Canyon upstream on the Colorado River. The depth of the Grand Canyon varies between 3,000 and 6,000 feet and the width from rim to rim between 4 and 18 miles. At my observation post on the south rim near Grand Canyon Village, I am standing on the Coconino Plateau which has an elevation of nearly 7,000 feet above sea level. The north rim, which is the southern part of the adjacent Kaibab Plateau, has an elevation of 8,000 feet, while the Colorado River below has an elevation of 2,400 feet.

AN ENORMOUS AMOUNT OF EROSION

My mind is drawn first to the colossal quantity of material which has been removed. Figure 2.4 shows the entire drainage basin of the Colorado River. Sedimentary strata, the major rocks forming the surface of the broad area known as the Colorado Plateau, have been deeply incised destroying the original continuity of the strata. In the Grand Canyon I see the breached remnants of once continuous strata. My simple calculation of the volume of the Grand Canyon shows that almost 1,000 cubic miles (4,000 cubic kilometers) of sediment was removed from northern Arizona to form just the topographic form of the canyon itself.

But this is not all the erosion. Beside the road just 16 miles south of Grand Canyon Village rises Red Butte, a prominent conical hill standing 1,000 feet above the present surface of the Coconino Plateau (see Figure 2.5). Red Butte is composed of shale of the Moenkopi Formation overlain by Shinarump Conglomerate of the Chinle Formation (the same formation outcropping at the Petrified Forest). This small butte stands on top of the Kaibab Limestone which forms the present Coconino Plateau.

The top of Red Butte is capped by a lava flow which has protected the underlying shale and conglomerate from erosion. (I asked myself how a lava flow could cover a butte, since lava does not usually flow over hills but around them. The answer is found by postulating that the lava flowed over a vast plain that existed 1,000 feet above the present south rim of Grand Canyon, and that the Moenkopi and Chinle formations covered the entire surface of the present Coconino Plateau above the Kaibab Limestone! Red Butte is simply an erosional remnant providing evidence of broad, sheetlike erosion of the Coconino Plateau.)

wrong This was in Science News.

The Coconino Plateau appears to have been buried even deeper than the 1,000 feet indicated by Red Butte. There is evidence above the Moenkopi and Chinle formations, which have now been eroded off the south rim, that the Glen Canyon Group (Navajo Sandstone, Kayenta Formation, Moenave Formation and Windgate Sandstone), another 2,000 feet of strata, were present as well. My

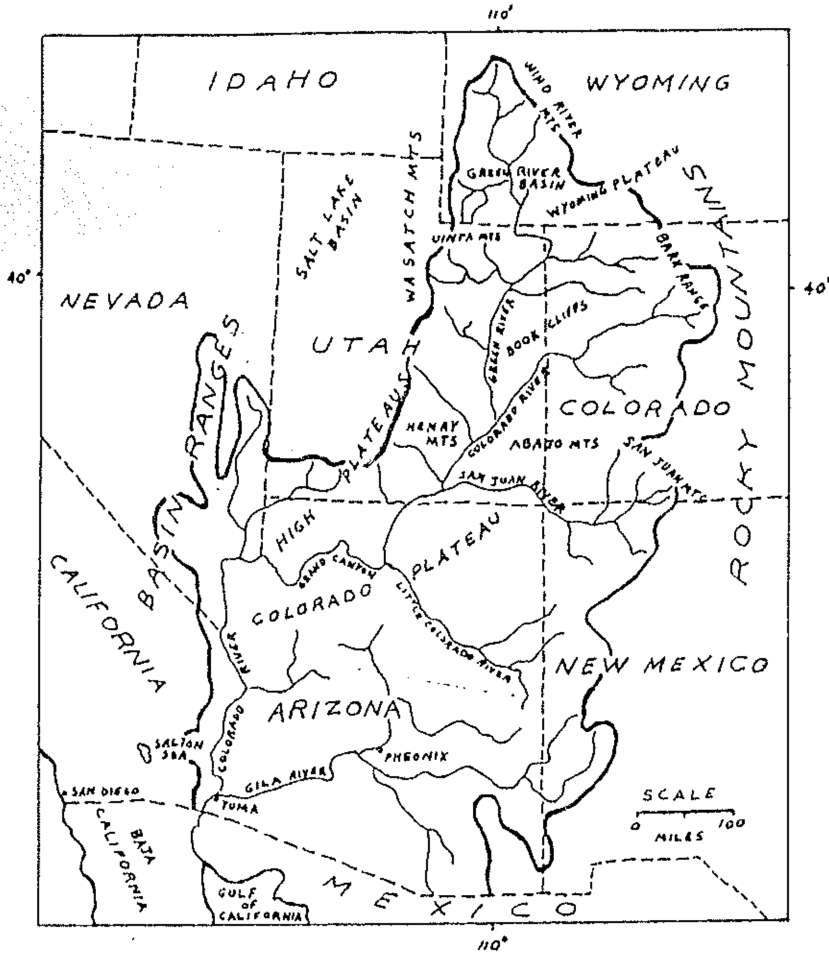


Figure 2.4 The drainage basin of the Colorado River
(after map of C. R. Longwell, 1946)

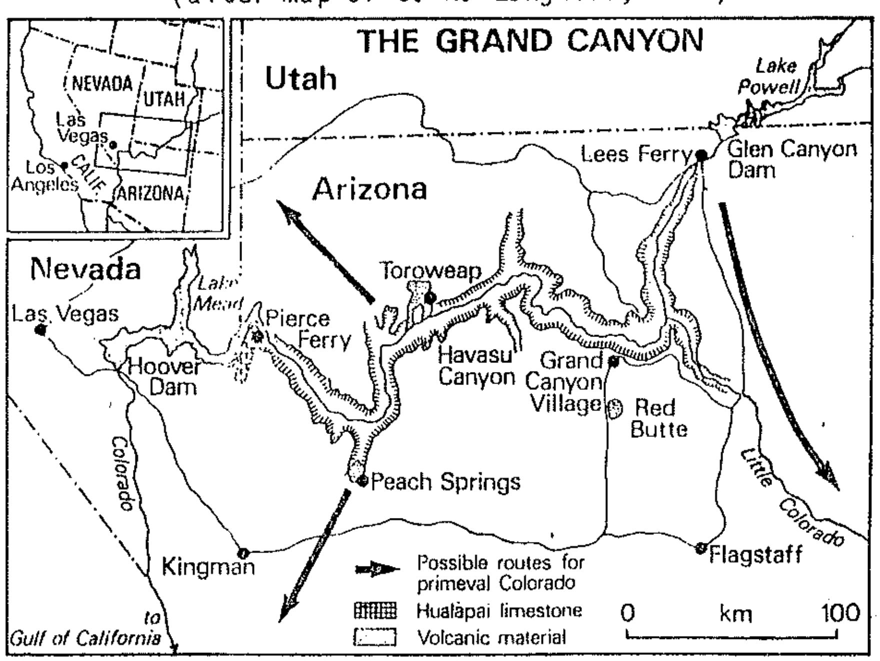


Figure 2.5 Possible routes of the primeval Colorado River
with locations of geologic features important to
theories on how the Grand Canyon was eroded.
(from R. J. Rice, 1983, The Canyon Conundrum, p. 291)

mind is staggered in its attempt to imagine not just the 1,000 cubic miles of canyon erosion, but many times that volume indicated by thousands of feet of erosion off the plateaus surround the Grand Canyon.

THE GRAND CANYON CUTS THROUGH THE PLATEAU

My second observation is even more startling than the first: the Grand Canyon cuts through, not around, a great plateau land. The well developed drainage basin of the Colorado River (see Figure 2.4) has its headwaters in elevated areas, as all rivers do, but unlike most rivers, it has high plateaus adjacent to it one third of its total length from the sea. Most rivers have broad lowland areas that close to the sea. I would expect the Colorado River to have established its course around, not through such an elevated area standing in its path to the sea.

Observation of the extreme eastern portion of the Grand Canyon shows the magnitude of this river location problem. At Grandview Point and Desert View Tower I observe the Colorado Plateau north and east of Grand Canyon. The plateau with its surface of Kaibab Limestone, to my astonishment, rises from an elevation of 5,000 feet near Glen Canyon Dam on Lake Powell to 7,400 feet at Grandview Point on the south rim. The north rim of the Grand Canyon across the Colorado River is the southern portion of the Kaibab Plateau (also the upper surface of the Kaibab Limestone) which has an elevation over 8,000 feet above sea level. The rise in the plateau land is caused by a north-south trending geologic fold structure called a monocline which flexes up the Grand Canyon strata and the plateau almost 3,000 feet on the west relative to the east. This fold structure forms the eastern flank of the Kaibab and Coconino Plateaus.

I expected that the Colorado River would have flowed southeast from its present entrance to Grand Canyon onto the lower terrain of Painted Desert in east-central Arizona. From there the Colorado River could have proceeded southeast to join the Rio Grande emptying into the Gulf of Mexico, or cut back toward the west through central Arizona to join the Gila River emptying eventually into the Pacific Ocean. The Colorado River, to my astonishment, does neither. Instead, the river is directed to the west straight through the plateau lands of northern Arizona to take a more direct route to the Pacific Ocean!

THE ANTECEDENT RIVER THEORY

When I first studied the Grand Canyon twenty five years ago, my pattern of thinking was uniformitarian. I conceived of great ages for strata and river basins, and I believed that erosion continued for millions of years at imperceptably slow rates to excavate canyons. During my education I was told that the uplift of the Colorado Plateau occurred during the Laramide Orogeny (70 to 50 million years ago in the standard way of thinking). As I observed the Colorado River drainage basin, I made the logically simple conclusion that the river was older than the plateau uplift and that the Grand Canyon is an enormously old feature that evolved directly from the uplift.

Figure 2.6 shows the theory that I had in my mind. The present course of the Colorado River was inherited from the location it had before the plateau land was uplifted. Very slow uplift on the Kaibab Upwarp beginning in late

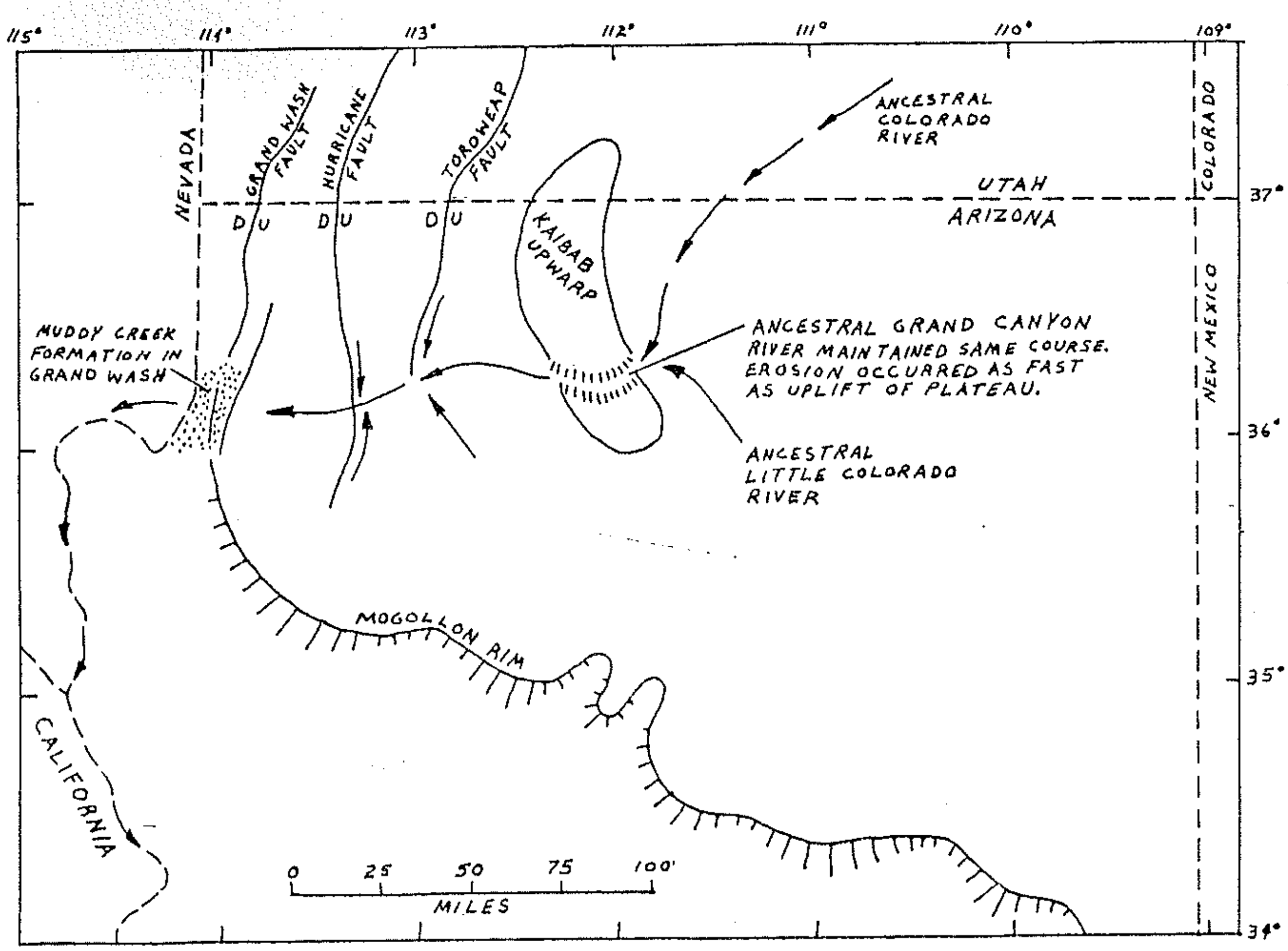


Figure 2.6 Explanation of how the Grand Canyon was eroded according to the antecedent river theory. Before the Kaibab Upwarp occurred seventy million years ago, the ancestral Colorado River was flowing westward through northern Arizona. The Grand Canyon was eroded by slow downcutting by the Colorado River as the Kaibab Upwarp occurred. The present course of the Colorado River was inherited from the ancestral river after tens of millions of years of uplift and erosion.

Cretaceous time was accompanied by equally slow erosion. Because the rate of uplift was precisely balanced by the rate of downcutting, the Colorado River was not diverted toward the southeast, but maintained its course as the Grand Canyon was eroded as the Kaibab Upwarp occurred. What I had in mind was a theory where the Colorado River location was antecedent to the uplift structure.

I learned that this theory had great explanatory power, and that many other geologists, including John Wesley Powell, had favored it. The antecedent river theory, for example, was able to explain the sheetlike erosion to the top of the plateau! I supposed that before the Kaibab Upwarp occurred the entire Colorado Plateau was near sea level. The primeval Colorado River would have been a slow, sluggish, meandering river in the Cretaceous Period which could have beveled the surface nearly down to sea level. The planation I conceived in my mind was what other geologists had called a "peneplain," the end product of many millions of years of erosion.

The antecedent river theory was extraordinary in its simplicity. It explained things rationally and reasonably in terms of processes which I could see and understand going on today. It was totally consistent with my education. All I had to do was assume that the canyon evolved slowly as uplift began 70 million years ago and had achieved its major form visible today just 50 million years ago. It was an elegant theory!

THREE MAJOR PROBLEMS WITH THE ANTECEDENT RIVER THEORY

My notion of an antecedent river had some fatal flaws. I could not allow my mind to rationally explain real and concrete data without contriving imaginary scenes which drew me away from what I actually saw. Among these problems were the following three.

Problem 1--Where has all the sediment gone?

The cutting of the Grand Canyon by the Colorado River would have produced vast quantities of clastic sediments. I expected these would be deposited just beyond the western end of the Grand Canyon near Pierce Ferry (see Figure 2.5). No great mass of gravel, sand, silt and clay is found there! Instead, at Pierce Ferry is found a relatively pure limestone bed (the Hualapai Limestone) 600 feet thick showing that no prolific supply of gravel, sand, silt and clay such as the Colorado River was situated nearby when the enlarged head of the Gulf of California was located over southern Nevada.

I tried to imagine how the extreme western end of Grand Canyon could be young allowing for deposition of limestone and lack of sand and gravel. I supposed that the ancestral Colorado River could have departed its present path southwest from Peach Springs or northwest from near Toroweap (see Figure 2.5) but such thinking required an "antigravity waterfall" which my mind found offensive.

Problem 2--Could the Colorado River erode for 70 million years?

? (My theory of antecedency) required that the Grand Canyon is a long-enduring feature left over from Cretaceous uplift of the Colorado Plateau, but

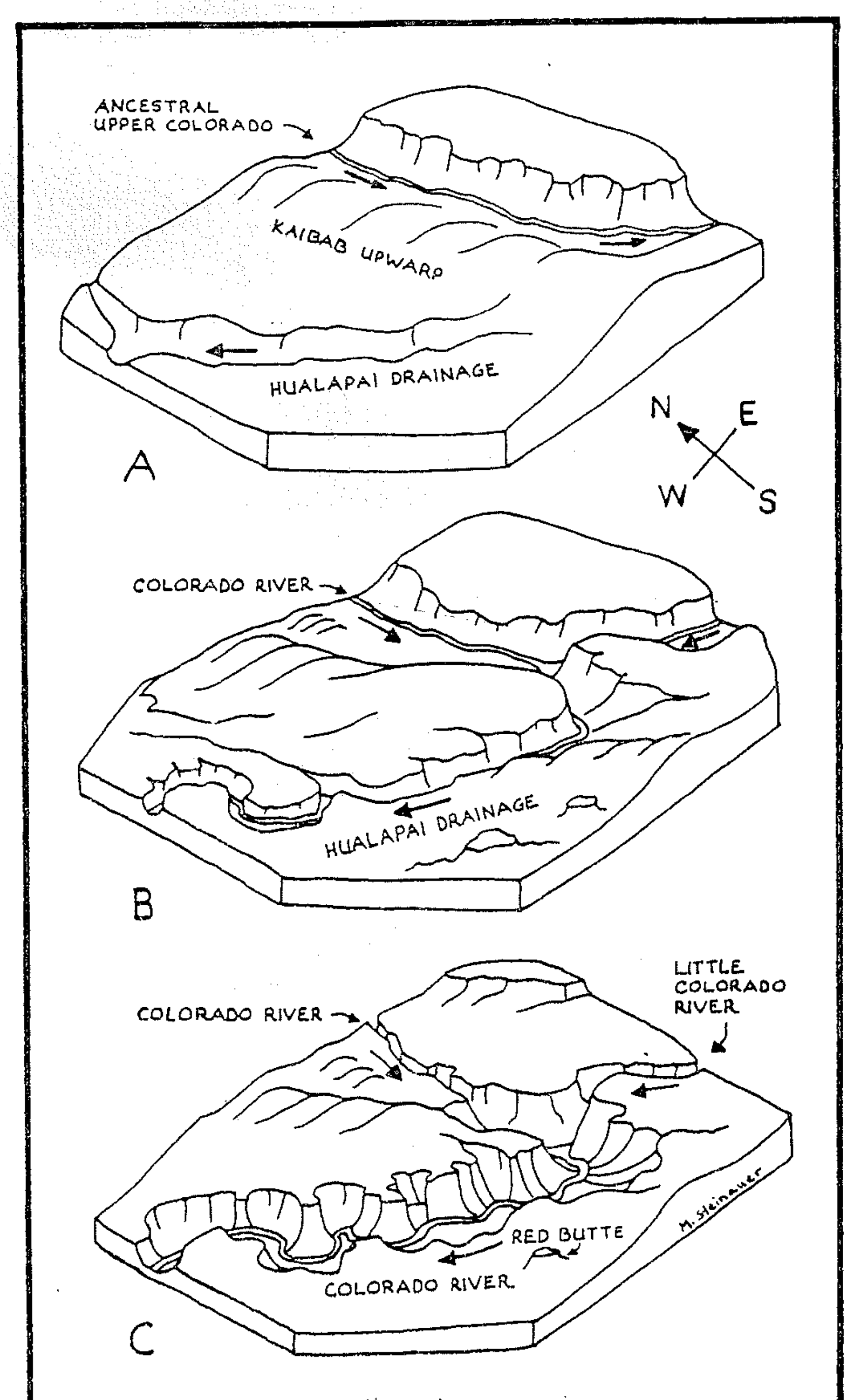


Figure 2.7 Block diagrams showing three steps supposing how the Grand Canyon formed according to the "Precocious Gully Theory." The repositioning of the Colorado River through the Kaibab Upwarp is supposed to have been achieved by a westward-flowing drainage which cut back and captured the south-flowing Colorado River.

for example, no east-west trending fault or zone of rock weakness to guide the gully as it enlarged and no trough-like sag in the plateau to straighten or direct the gully. Furthermore, the drainage must have been very long, straight and deep without much branching, all features I knew are not characteristic of enlarged gullys. Last, the gully must enlarge to the east through a sloping plateau which has drainage to the south.

A well-intentioned geologist friend of mine recognized the problems I was having conceptualizing the gully. He proposed that I visualize the capture of the Colorado River through the Grand Canyon area not by a gully, but by a cave. Could a cave have diverted the original drainage of the Colorado River? If so, the present Grand Canyon could have formed by the collapse of that cave. We both smiled and shook our heads when we considered the direction our speculations had led us.

Problem 2--Could the plateaus in Northern Arizona endure as an uplifted landscape for 70 million years?

Although this new theory did not require the Grand Canyon to be several tens of millions of years old, I was still supposing that the Colorado River and the Laramide uplift of the plateau dated back 70 million years. As mentioned previously, 70 million years of erosion should severely alter the uplifted plateau. There should have been intense erosion generally to the plateau lands, not just deep erosion in one enlarged gully. My theory left this problem unexplained.

Problem 3--Where are the evidences of the long-continued operation of the ancestral upper Colorado River?

Because I still assumed that the Kaibab Upwarp occurred 70 million years ago while the amazing stream capture was completed less than 9 million years ago, I was obligated to have the ancestral upper Colorado River located east of the Kaibab Upwarp for 60 million years. I would expect significant erosional and depositional features would be obvious. No obvious abandoned channel for my postulated river can be found southeast of the Grand Canyon. If the upper Colorado River eroded as it does today, I would expect it to have generated nearly one million cubic miles of sediment. Although some thin alluvial sediments are found in eastern Arizona (the Bidahochi Formation), no colossal quantity needed by long continued erosion occurs east of Grand Canyon.

THE CATASTROPHIC DRAINAGE THEORY

My thinking regarding the Grand Canyon went through two very significant modifications. First, I learned that the Colorado River acting incessantly during 70 million years could not carve the canyon. Second, I also came to realize that attributing the canyon to stream capture from a much-enlarged gully required mental gymnastics that my brain could not accomplish. Both theories assumed the ancestral Colorado River to have operated for 70 million years, but ultimately that assumption worked contrary to forming the very geologic structures I was trying to explain. Could it be that I was laboring with a concept of geologic time that really did not exist? Twenty years ago I became skeptical of the millions of years conventionally assigned to rocks by radiometric dating and began to consider catastrophist explanations for geologic data. I learned of a third theory which explains the erosion of the Grand Canyon, a theory which supposes it to be a geologic relict, a landform which has survived decay and disintegration being left behind by catastrophic drainage which is not now operating.

I was amazed to learn that the catastrophic drainage theory is contained in legend and is the oldest explanation for the origin of the Grand Canyon. According to the Havasupai Indians, who still tell the story in their villages within the Grand Canyon, the immense chasm formed after the world was covered by a great flood. Pu-keh-eh, daughter of the good god Tochapa, was placed in a hollowed out trunk of a tree and survived when the evil god Hokomata caused the waters to rise so severely that the earth was covered. When the flood retreated, mountain peaks emerged and rivers were produced. One of these great gushing rivers cut the Grand Canyon. From the mortal children of Pu-keh-eh came all the people of the earth including the Havasupai, which Tochapa commanded to live at peace within the Grand Canyon.

The Havasupai legend is immediately recognizable as one of hundreds of flood traditions which are known worldwide, of which the Biblical account of Noah's Flood is the most detailed and accurate. If the Flood was involved in forming the Grand Canyon, then it would be a relict feature formed from erosive processes which had operated at rate and scale far greater than today. The Grand Canyon would be a largely dead monument to the action of intense ancient processes, not a constantly evolving landform in equilibrium with slow, modern, erosive processes as I had earlier assumed.

No

My mind began again to consider the geologic evidence at Grand Canyon. As explained before, it seems certain that the Kaibab Upwarp was established before the Colorado River was positioned across northern Arizona. Could the uplift of the plateau have created a drainage basin east of Grand Canyon which completely filled with flood water? Could the large dam created by the Kaibab Upwarp have been breached allowing the "lake" behind it to drain over the plateau through northern Arizona initiating the erosion of Grand Canyon?

There is evidence that an impounded mass of water existed on the east side of the Kaibab Upwarp. Geologists call the sedimentary deposits restricted to the east of Grand Canyon the Bidahochi Formation. They contain regular layers of silt and sand which look like lake deposits which would have been deposited from accelerated erosion in the drainage basin now occupied by the upper Colorado River. These are thin strata that represent a short time geologically (classed as Pliocene by many geologists). The Bidahochi Formation does not provide evidence of impoundment of the ancestral upper Colorado River for tens of millions of years as my theories once required.

I know of several dams which have been breached catastrophically producing significant canyon erosion. In fact, it seems that dams do not fail slowly, but catastrophically. My favorite example is the erosion on the North Fork of the Toutle River in Washington after the recent eruptions of Mount St. Helens. The valley of the North Fork of the Toutle River had been blocked by up to 600 feet of landslide debris and volcanic ash on May 18, 1980. Then on March 19, 1982, mud and water rapidly breached the blockage to the valley creating an elaborate canyon system resembling the Grand Canyon, but at one-fortieth scale. Figures 2.8 and 2.9 show the new canyon next to Mount St. Helens.

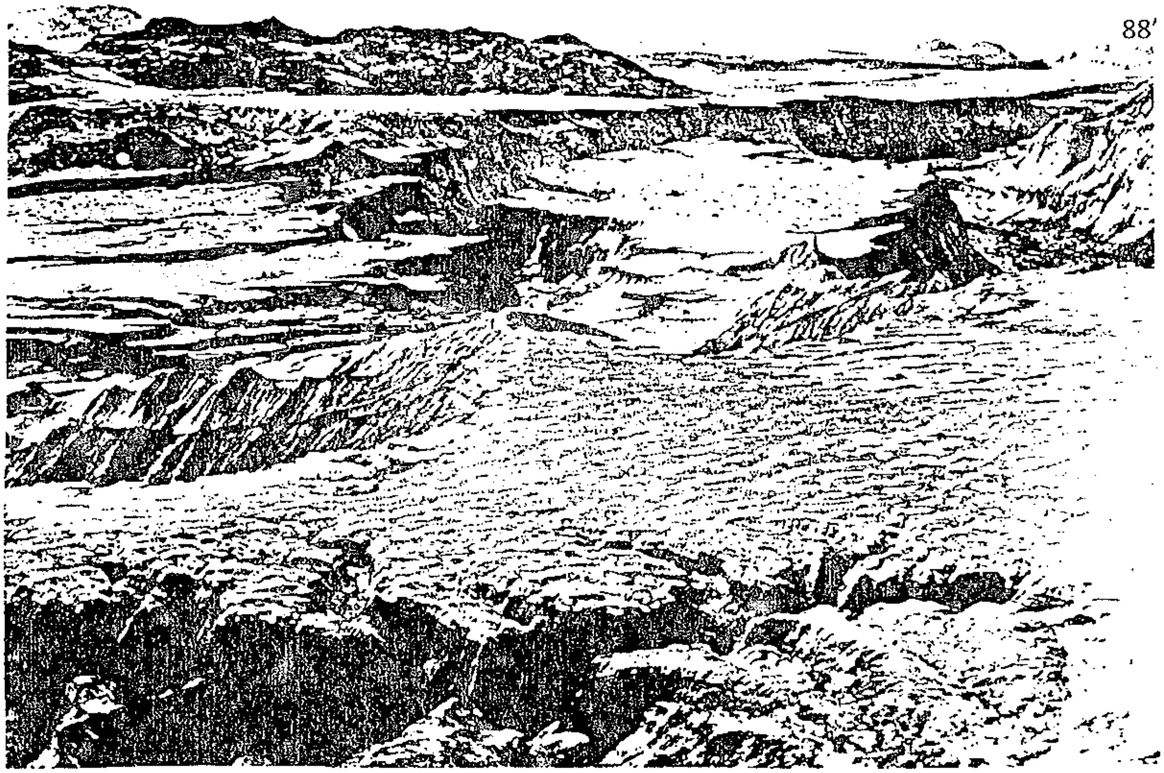


Figure 2.8 The "Little Grand Canyon of the Toutle River" is a relict canyon system on North Fork of the Toutle River just north of Mount St. Helen's volcano. The rockslide and pumice deposits from the 1980 eruptions had been breached by mudflow on March 19, 1982, to form a dendritic system of canyons up to 140 feet deep. (Photo by Steven A. Austin)

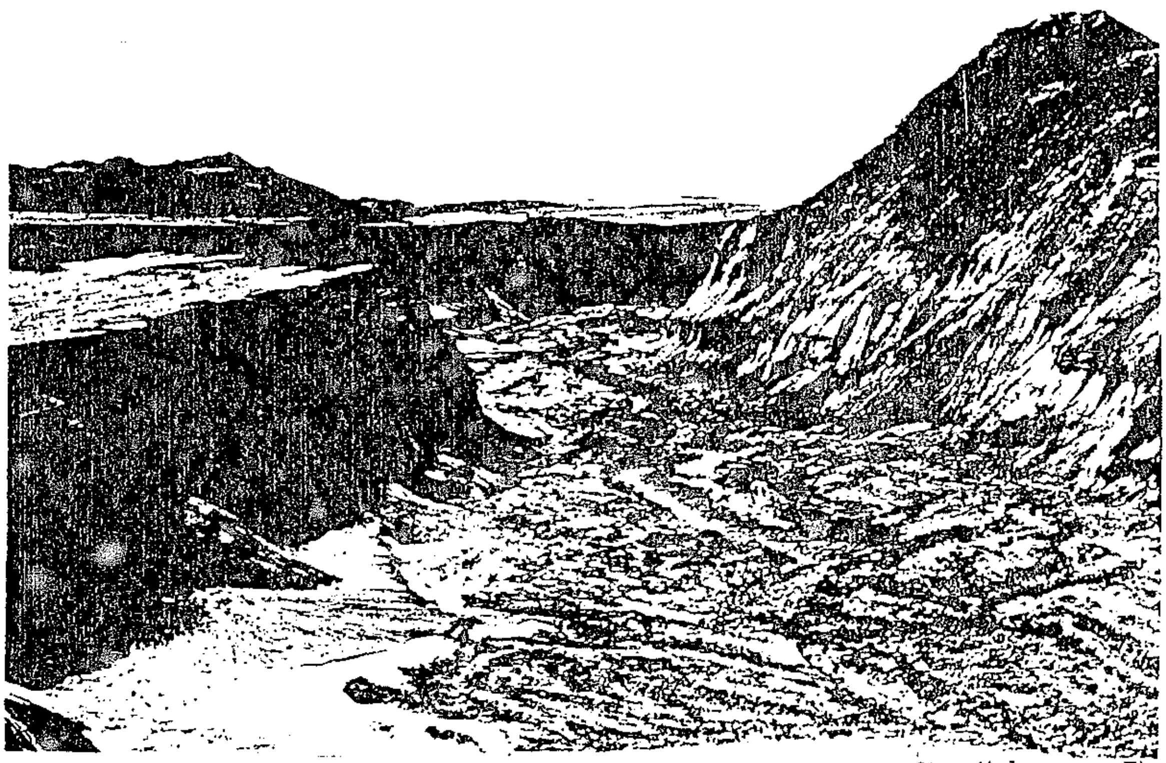


Figure 2.9 Detail of one of the relict canyons at Mount St. Helens. The volcanic deposits had been eroded over 100 feet deep to form this canyon within two years. The small stream in this canyon did not erode this canyon. (Photo by Steven A. Austin)

EVIDENCES FOR RELICT LANDSCAPE AND YOUTHFUL CANYON

If the Grand Canyon was eroded largely by catastrophic drainage of impounded water behind the uplifted plateau, I would expect the landscape to show marks of erosion by energetic agents. My attention is drawn to many features which appear to be stagnant, not evolving. The prominent slopes of the canyon are dominantly in an arrested stage of development. An excellent example is the cliff of Redwall Limestone which has an accretionary reddish coating derived from overlying Supai redbeds dominating its exposure. This cliff is not now slowly eroding back through a major extent of the canyon. Another example is the Vishnu Schist of the inner gorge which is dominated by an accretionary coating of desert varnish, another chemically attached residue on to the rock surface.

I also notice that the very low relief surface of the plateaus which form the north and south rims of the Grand Canyon are landforms which are not now evolving. When I favored the antecedent river and precocious gully theories, I had to apologize for the plateaus assigning them to pre-Laramide erosion by sluggish rivers near sea level. I marvelled at how such landforms could endure as elevated features for tens of million years. The catastrophic drainage theory I now favor easily accomplishes the plateau erosion by sheet flow of the flood waters over the plateau surface before the water became channelized to erode the canyon. I no longer need to explain why the plateaus have endured millions of years, because I no longer regard them as that old, but recent features, which could be thousands of years old.

Hundreds of smaller side canyons branch off from the Colorado River in the Grand Canyon. What is interesting is that these side canyons are typically short, rather wide, quite deep and have bowl-shaped heads ("amphitheatre" heads). These side canyons of this shape are not typical of enlarged gullys which usually have narrow V-shaped heads. I could not conceive of a very old river canyon having such short and wide features. Instead, such amphitheater-headed side canyons remind me of collapse features formed where water oozes out of wet sediment causing the supporting layers of sediment or rock to be removed so collapse occurs. Technically, this process is known as "sapping" and would have been an important process as greatly enlarged flow through the main canyon down cut and caused poorly consolidated sediment marginal to the canyon to dewater and slump into the main canyon. These amphitheater-headed canyons today rarely have springs at their heads, and, therefore, can be recognized to be relict features. They resemble some of the side canyons formed by catastrophic erosion on the North Fork of the Toutle River in 1982 after the eruptions of Mount St. Helens.

Evidences can be found for increased water flow in the past on the Colorado River. Just upstream from Grand Canyon in Marble Gorge, the channel of the Colorado River forms incised meanders. Laboratory experiments indicate that these elaborate meandering canyons could not have formed by the continued action of the present river. Greater water flow was required. Thus, the present Colorado River can be considered "underfit" relative to its canyon. there

Another evidence of increased water flow in the past comes from consideration of cliffs near the Colorado River, especially upstream from Grand Canyon where broad flat benches of shale occur below sandstone and limestone cliffs. If such cliffs are the result of continuous slow erosion over hundreds of thousands of years, we might expect a progressive increase in the decomposition of talus on the benches away from cliffs. Such boulder aging has not been demonstrated. Instead, we see shale benches which appear to have been swept clean of larger rocks by large flooding. Then after significant flood modification, a recent talus has accumulated.

When I favored the antecedent river and precocious gully theories, I had the problem of explaining where the products of 70 million years of river erosion went. I could not find appropriate erosional or depositional features to the west or east of the Grand Canyon which would have been produced by the long-continued action of the primeval Colorado River, and I knew that such incessant river action would erode and deposit one million cubic miles of material. With the catastrophic drainage theory there is no requirement for the Colorado River to erode for tens of millions of years because the river only needs to be thousands of years old. The lack of features which would be produced by an old river is an argument for a young river. The vast erosion off the plateaus could be produced by sheet flooding when the flood water retreated off the plateaus. It would have removed the sediment far from the plateaus. We would expect no stream deposits adjacent to the plateau. Then, after the Kaibab Upwarp occurred, impounded water behind the plateau was released by catastrophic breaching and drainage. The Grand Canyon and the establishment of the Colorado River through northern Arizona would be very recent geologic features. This explains why the products of the Colorado River's erosion and sedimentation are confined to near-surface sedimentary layers.

CONCLUSION

There will need to be more investigations of how the Grand Canyon was eroded. The notion that the Colorado River carved the canyon, as the antecedent river theory assumes, over millions of years is untennable and now recognized so by most geologists. The concept of Grand Canyon erosion from stream capture by enlargement of a gully involves an accident of incredible improbability. The explanation of recent erosion of the canyon in association with catastrophic drainage from a great flood seems to integrate and coordinate a great number of facts in believable fashion. I found that the statements of Scripture provide an acceptable framework for interpreting the erosion of the Grand Canyon.

BIBLIOGRAPHY ON GRAND CANYON EROSION

Anonymous, 1985, Grand Canyon legend: Ex Nihilo, v. 7(3), p. 11.
(Review of the catastrophic drainage legend of the Havasupai who live in the Grand Canyon.)

Austin, S.A., 1984, Rapid erosion at Mount St. Helens: Origins, v. 11, no. 2, pp. 90-98.
(Analysis of blocked and breached drainage of the North Fork of the Toutle River which has a miniture "Grand Canyon" formed by catastrophic erosion since 1980.)

Blair, Will N., 1978, Gulf of California in Lake Mead Area of Arizona and Nevada During Late Miocene Time: American Assoc. Petroleum Geologists Bulletin, v. 62, p. 1159-1170.
(Stratigraphy and radiometric dates establish Colorado River gravels as post-Miocene west of Grand Canyon. This disputes the antecedent river theory.)

Gregory, Herbert E., 1947, Colorado drainage basin: American Journal of Science, v. 245, p. 694-705.

Hunt, C. B., 1976, Grand Canyon and the Colorado River, their geologic history, in W. J. Breed and E. Roat, eds., Geology of the Grand Canyon: Flagstaff, Museum of Northern Arizona, second ed., p. 129-141.
(Hunt maintains that the Colorado River is very old. He supposes the river reached Nevada by drainage through caves in northern Arizona.)

Laity, Julie E., and Malin, Micahel C., 1985, Sapping processes and the development of theater-headed valley networks on the Colorado Plateau: Geological Society of America Bulletin, v. 244, no. 12, p. 817-835.
(Description of the sapping process in the Glen Canyon region.)

Lovejoy, E. M. P., 1980, The Muddy Creek Formation at Colorado River in Grand Wash: the dilemma of the immovable object: Arizona Geological Society Digest, v. 12, p. 177-192.
(Lovejoy defends the antecedent river theory with some very clever, but highly improbable, reasoning.)

Lucchitta, Ivo, 1972, Early history of the Colorado River in the Basin and Range province: Geological Society of America Bulletin, v. 83, p. 1933-1948.
(Evidence presented for Pliocene establishment of Colorado River through northern Arizona.)

McKee, E.D., Wilson, R.F., Breed, W.J., and Breed, C.S., 1967, Evolution of the Colorado River in Arizona--a hypothesis developed at the symposium on Cenozoic geology of the Colorado Plateau in Arizona, August 1964: Museum Northern Arizona Bulletin 44, 67 p.
(This symposium volume critiques the antecedent river theory and suggests, without technical defense, the stream capture theory. No hint of the catastrophic drainage theory is presented.)

McKee, E.D., and McKee, E.H., 1972, Pliocene uplift of the Grand Canyon region--time of drainage adjustment: Geological Society of America Bulletin, v. 83, p. 1923-1932.
(Gravel deposits used to argue that the Colorado River was not positioned in northern Arizona until Pliocene time.)

Powell, John Wesly, 1875, Exploration of the Colorado River of the West and its tributaries: Washington, D.C., United States Government Printing Office, 291 p.
(The classic geologic description of Grand Canyon suggesting the antecedent river theory which, over the years, was so popular with geologists.)

Rice, R.J., 1983, The Canyon conundrum: Geographical Magazine, v. 55, pp. 288-291.
(Concise explanations and critiques of antecedent and stream capture theories for the origin of Grand Canyon.)

Rogers, J. D. and Pyles, M. R., 1980, Evidence of catastrophic erosional events in the Grand Canyon: Proceedings of the Second Conference on Scientific Research in the National Parks, v. 5, p. 392-454.
(The authors present evidences for catastrophic drainage of large lakes within and to the northeast of Grand Canyon.)

Smith, W. O., et. al., 1960, Comprehensive survey of sedimentation in Lake Mead, 1948-1949: U. S. Geological Survey Professional Paper 295, 254 p.
(For the period 1926-1950 the sediment load of the Colorado River at Grand Canyon averaged 168 million tons per year.)

Young, Richard A. and McKee, E. H., 1978, Early and middle Cenozoic drainage and erosion in west-central Arizona: Geological Society of America Bulletin, v. 89, p. 1745-1750.
(The authors argue that the Colorado River is not antecedent to the uplift in northern Arizona.)

STRATA OF THE GRAND CANYON--A CREATIONIST VIEW

by Steven A. Austin

After the initial amazement of viewing the Grand Canyon wears off, your attention may become focused on the strata so marvelously exposed. This enormous chasm reveals a sequence of strata more prominently displayed than on any other spot on earth. How did the layers form? Which sedimentary processes were responsible for depositing these strata? How do these processes relate the historical framework of Scripture? Do the strata of the Grand Canyon provide evidence of rapid deposition and a young earth? Or, must we assume over one billion years of history as supposed by evolutionists?

FOUR MAIN DIVISIONS OF GRAND CANYON STRATA

Creationists have divided the rocks of the Grand Canyon into four major groups according to their association with the historical framework of Scripture. The sequence of strata and the corresponding epoch of earth history is suggested in Figure 2.10 which is an idealized cross section of the strata of the Grand Canyon region.

The first, oldest, and most deeply buried rocks are crystalline igneous and metamorphic rocks (Vishnu Group and Zoroaster Granite) which lie below the various stratified rocks of the canyon. These deeply buried rocks are believed to represent the crust of the early earth during Creation Week.

The second division and oldest stratified rocks occur as tilted and faulted sedimentary rocks (Grand Canyon Supergroup) buried in most places below horizontal strata. These deeply buried, tilted strata appear to provide evidence of sedimentary and tectonic processes during and after Day Three of Creation Week. Some of the uppermost strata within this division appear to represent normal sedimentation in the post-Creation but pre-Flood ocean. Everywhere these strata occur they are bounded above by a very conspicuous planar surface of erosion (the "Great Unconformity") believed to represent early erosion and the onset of Noah's Flood in northern Arizona.

The third division of strata comprises the canyon's characteristic, horizontally stratified layers (the so-called "Paleozoic and Mesozoic strata") which are several thousands of feet thick. These represent broad sedimentary deposits of Noah's Flood in northern Arizona.

The fourth division and youngest group of strata were deposited in response to more than one mile of vertical uplift of the Colorado Plateau after the major erosion of the canyon had been accomplished. These most recent strata include river terrace gravels, lake sediments, landslide deposits, and lava flows of the post-Flood period.

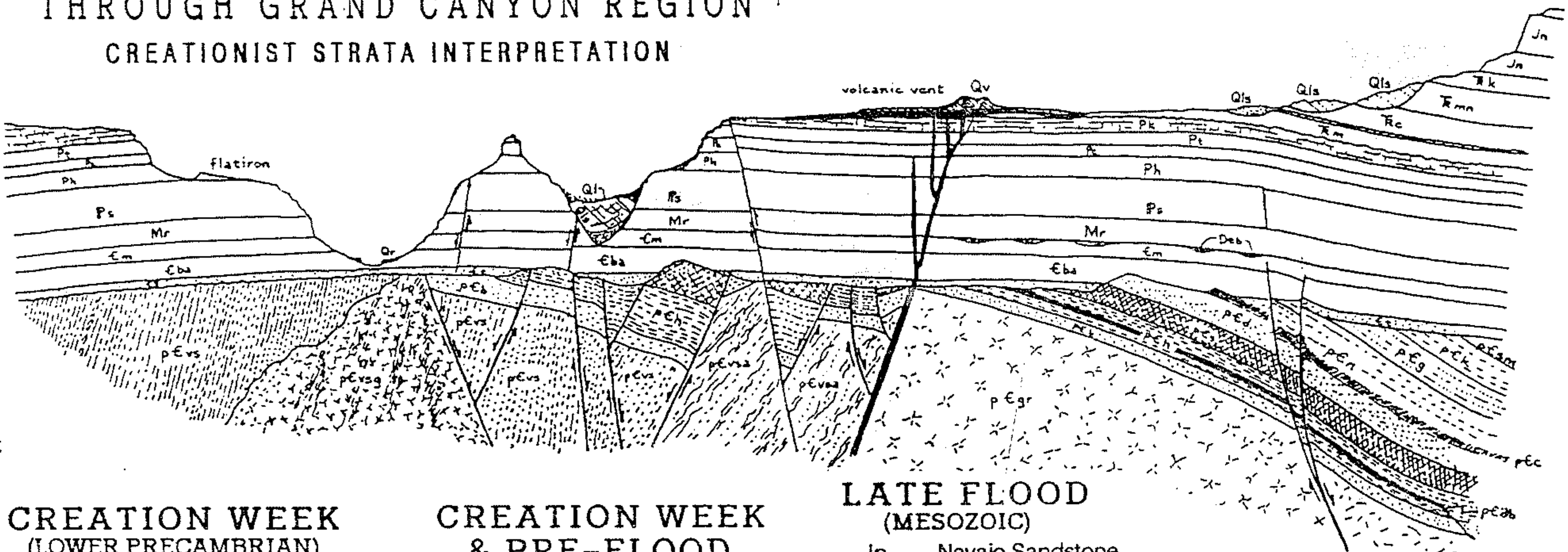
DETAILS OF GRAND CANYON STRATA

Beginning with the lowest and earliest rock units and climbing up the strata sequence, we can discern the order of formation of the Grand Canyon region. The sequence described below can be seen in Figure 2.10, a geologic cross section. This cross section is diagramatic and idealized, shortening the horizontal distances between formations to show their vertical position

FIGURE 2.10

IDEALIZED GEOLOGIC CROSS SECTION THROUGH GRAND CANYON REGION

CREATIONIST STRATA INTERPRETATION



CREATION WEEK
(LOWER PRECAMBRIAN)

p€gr	Zoroaster Granite
p€vs	Vishnu Schist (includes gneiss and amphibolite)

CREATION WEEK & PRE-FLOOD
(UPPER PRECAMBRIAN)

p€sm	Sixtymile Formation
p€k	Kwagunt Formation
p€g	Galeros Formation
p€n	Nankoweap Formation
p€c	Cardenas Lavas
p€db	Diabase Intrusions
p€d	Dox Sandstone
p€s	Shinumo Quartzite
p€h	Hakatai Shale
p€b	Bass Formation

LATE FLOOD
(MESOZOIC)

Jn	Navajo Sandstone
₨k	Kayenta Sandstone
₨mn	Moenave Formation
₨c	Chinle Formation
₨m	Moenkopi Formation

EARLY FLOOD
(PALEOZOIC)

Pk	Kaibab Limestone
Pt	Toroweap Formation
Pc	Coconino Sandstone
Ph	Hermit Shale
IPs	Supai Group
Mr	Redwall Limestone
Dtb	Temple Butte Limestone
€m	Muav Limestone
€ba	Bright Angel Shale
€t	Tapeats Sandstone

POST-FLOOD
(CENOZOIC)

Qv	Pleistocene Lava Flows
Qls	Landslide Deposits
Ql	Lake Sediments
Qr	River Terrace Gravels

more clearly. Most of these formations can be seen in the eastern Grand Canyon, the focus of our study and tour. Knowledge of the rock units of Figure 2.10 is required to correctly understand the origin of Grand Canyon rocks and relate them correctly to the framework of Scripture. The strata can be read like pages of a book and provide the data from which we can weave our theories and discussion. Let's begin with the rock layers and see if we can relate them to the sequential, literal understanding of Genesis Chapter One and a dynamic, global Flood.

Vishnu Schist - Nonstratified metamorphic rocks, specifically chlorite mica schist with minor amounts of amphibolite, gneiss and calc-silicate rock. These metamorphic rocks form prominent greenish brown cliffs in the Inner Gorge being the deepest and oldest rocks of the canyon. Creationists relate these rocks to the first events of Creation Week. What the Vishnu Schist was derived from remains uncertain.

Zoroaster Granite and Granodiorite - Nonstratified crystalline rocks rich in pink feldspars (the mineral orthoclase), sometimes richer in dark minerals (mafic minerals, especially biotite, hornblende and pyroxene), with intrusive contact with Vishnu Schist. Pegmatite dikes of the Zoroaster composition are common as distinct pink-colored "veins" which penetrate Vishnu Schist. Molten material appears to have been injected into cracks perhaps during the upheaval of continents and formation of oceans on the third day of Creation (Genesis 1:9).

Nonconformity - A buried, very low relief surface of erosion occurs above Vishnu and Zoroaster rocks and below sedimentary strata of the Unkar Group. The retreat of waters into the newly created ocean basins (Genesis 1:10) would first initiate erosion, then cause overlying sedimentation as the waters collected in their basins.

Unkar Group - A thick sequence of tilted strata overlies Vishnu Schist and Zoroaster Granite. These strata of conglomerate, limestone, shale, sandstone and lava flows appear to represent the deposits of Day Three of Creation Week and residual sedimentation after Day Three (see Genesis 1:9-13). These strata are notably devoid of fossils. There are five formations recognized in the Unkar Group, with a total thickness of about 5,320 feet. Beginning with the lowest unit and moving up we have:

> **Bass Formation** - Impure sandy limestone and interbedded shales 250 feet thick. Contains ripple marks, syneresis cracks (incorrectly called "mud cracks") and concentrically zoned masses which some have supposed to be fossil algae. Whether there are algae fossils here, however, remains uncertain. Locally, the Bass contains the Hotauta Conglomerate Member at its base which contains pebbles of Vishnu Schist and Zoroaster Granite. Dolomite casts of gypsum crystals have been described from the Bass indicating that the water which deposited the limestone and shale was rich in oxygen. This would seem to refute the evolutionist's supposition that the original earth had a reducing atmosphere.
>
> **Hakatai Shale** - Brown to red sandy shale 600 to 1,000 feet thick. The upper part of the formation is bright vermilion and is one of the most conspicuous colors in the canyon. The red coloration is due to oxidized iron. The formation contains ripple marks, syneresis cracks and

cross-bedding. Fossils are doubtful. In many areas the Hakatai Shale has been intruded by an igneous sill of diabase. The heat from the igneous material cooling nearby may have caused the oxidation and red color of the Hakatai Shale. Three subdivisions of the Hakatai have been recognized: red mudstone at the base, orange mudstone in the middle and purple sandstone toward the top. The formation thickens westward.

Shinumo Quartzite - Quartzose sand firmly cemented with silica with very little clay or silt produces a red, brown or purple sandstone. The formation averages 1,200 feet thick with thickness increasing westward. An unusual disruption of the sandstone layers (convolute bedding) argues for very rapid sedimentation before full compaction could occur. Because of its resistence to weathering the Shinumo is a dominant cliff-forming unit in the Inner Gorge. Contains cross-bedding and ripple marks indicating water currents. No fossils have been found in this formation.

Dox Formation - Red, thin-bedded siltstones and shales with a few thin limestones with a thickness recently measured of 3,122 feet. Forms characteristic rounded hills in the bottom of the eastern canyon below Desert View.

Diabase Sills - Dark coarse grained gray to black diabase (the intrusive equivalent of basalt) frequently intruded as sills and dikes in the Hakatai Shale or Bass Formation. Some of the wider diabase dikes may represent the cracks through which molten rock was erupted to form the overlying Cardenas Lavas.

Cardenas Lavas - Brownish gray basalts and basaltic andesites with a thickness of 980 feet. Lava flows poured out over the ocean floor as indicated by pillow basalts and interbedded sandstone beds. The basalts overlie the Dox Formation without obvious scour or erosion to the top of the Dox. The Cardenas Lavas were dated using the rubidium-strontium isochron method at 1.09 billion years, but the Western Grand Canyon Lava Flows (described later) gave an age of 1.5 billion years, but are clearly much younger than the Cardenas Lavas.

Nankoweap Formation - White, brown and purple sandstones averaging 330 feet thick. The sandstones contain ripple marks, syneresis cracks, and cross-bedding. The Nankoweap rests with disconformity on the Cardenas Lavas of the Unkar Group, and has recently been assigned formation status above the Unkar Group and below the Chuar Group.

Chuar Group - In a very remote section of the extreme eastern portion of the canyon on the north side of the Colorado River, shale, sandstone, limestone and breccia overlie the Nankoweap Formation and the Unkar Group. Called the Chuar Group, assigned to the uppermost Precambrian, and divided into three formations (Galeros, Kwagunt and Sixtymile), the group has a measured thickness of 6,610 feet. The Sixtymile Formation, which forms the uppermost 120 feet of the Chuar Group, is composed of sedimentary breccia formed by rapid tectonic disruption and breakage of the underlying, poorly consolidated Chuar shales. Evidently, as the Flood began, the Precambrian strata in the eastern canyon were deformed into a huge, north-trending trough structure ("syncline") which lowered them into the earth enough so that subsequent Flood erosion did not completely remove them. At the same time the shale clasts now composing the Sixtymile Formation were redeposited by slumping and sliding as great masses of Chuar shale eroded. The evidence seems to favor the interpretation that most of the Chuar Group is pre-Flood (perhaps mostly representing the first, 1,656 years after Creation) with only the uppermost 100 feet representing redeposition by the initial upheaval beginning the Flood. More study on these strata is needed. No indisputable multicellular fossils have been found in these remote, poorly studied rocks. Colonial algae form some interesting limestones of the Chuar. These indicate that a shallow ocean covered northern Arizona before the Flood.

The Great Unconformity - Erosion surface overlying both the tilted stratified Precambrian rocks and the Vishnu and Zoroaster rocks. This unconformity in the canyon may be the best example of an unconformity visible in the whole world. Local relief of up to 300 feet is known on the surface over Shinumo Quartzite. Without doubt, this is the major unconformity in the canyon, and it probably exists through a major portion of the North American continent and perhaps on other continents. The magnitude of this unconformity should be an excellent topic for discussion. The tilting and erosion of the Precambrian strata below the Great Unconformity has been related to the upheavals involved with the onset of Noah's Flood by most creationist geologists. Sedimentary rocks of the underlying Unkar Group must have been eroded when in a lithified state because boulders of Shinumo Quartzite directly overlie the Great Unconformity and form an integral part of the base of the Tapeats Sandstone.

Tapeats Sandstone - Medium to coarse grain, brown sandstone 200 to 300 feet thick with amazing uniformity of thickness over thousands of square miles. The sandstone is locally absent where Shinumo Quartzite high areas below the Great Unconformity show relief of as much as 300 feet. The Tapeats Sandstone contains abundant thin horizontal beds, thin graded beds, and thin cross beds. Cross-bedding is trough and hummocky in form and dips consistently toward the west and southwest, indicating that this was the dominant direction of the water currents which deposited the sand. Evidently the cross beds represent oceanward bottom surge as the Flood advanced eastward over the continent. Deep water and catastrophic processes are indicated by quartzite megabreccia at base of sandstone around Shinumo Quartzite highs. One boulder measured by Dr. Austin was 15 feet in diameter, weight of 200 tons and was moved over one-quarter mile by a powerful submarine landslide. Worm trails and tracks of trilobites indicate the ocean was over the area. The formation thickens into Nevada where it has a strata sequence below it over the Great Unconformity. The Tapeats Sandstone is assigned to the Cambrian System in the standard strata classification. This formation appears to represent the first sedimentary deposit from advancing water of Noah's Flood, most likely within the first 40 days as the continent was submerged. The Tapeats Sandstone in Nevada has formations conformably occurring underneath it. This indicates that the waters of the Flood got to Southern Nevada earlier than they got to Northern Arizona. The top of the Tapeats intertongues with the Bright Angel Shale.

Bright Angel Shale - Greenish buff, silty to sandy shale from 350 to 400 feet thick. Prominent beds of sandy dolomite and silty limestone are very persistent within the shale throughout the canyon. Green sandstones containing glauconite and dark brown ironstone are also common. The Bright Angel Shale is very easily eroded and forms the widest bench at any level in the canyon (the Tonto Platform). Marine fossils include trilobites (Olenellus and Glossopleura common), trails, burrows and thin-shelled brachiopods (Lingulella and Paterino). Assigned to Cambrian System. The Bright Angel Shale represents deeper water and slower currents than the Tapeats Sandstone as the continent was more deeply submerged. The top of the Bright Angel Shale intertongues with Muav Limestone.

Muav Limestone - Yellowish brown, impure silty and sandy limestone up to 500 feet thick. Distinguished from underlying Bright Angel Shale by the lack of greenish color. The Muav Limestone usually forms cliffs with small, irregular inclusions of mud above the Bright Angel Shale. Assigned to the Cambrian System. Waters from the Flood were deeper than for Tapeats or Bright Angel Shale when Muav was deposited, and current action was the slowest. (The calcium carbonate sediment source was probably located west of the canyon.) Because the Tapeats, Bright Angel and Muav are not separated by unconformities but grade into each other, they have been collectively called the Tonto Group.

Disconformity - A type of unconformity with a surface of slight relief where sedimentary rock strata overlie sedimentary rock strata without evidence of tectonic tilting or faulting. About 30 feet of channelling can be seen locally, but this disconformity has been interpreted to include the erosion of the Ordovician and Silurian Systems, supposedly accumulated and eroded over a period of 100 million years! Is such a long interval justified by the physical evidence? Does the surface represent a period when the marine strata below were uplifted out of the ocean, lithified and then eroded to a plain? Might the disconformity represent a surface of erosion of soft sediment rather than a surface of erosion of lithified rock? Evidently the Flood waters got shallower and bottom current velocity increased allowing soft sediments to be eroded as sedimentation stopped.

Temple Butte Limestone - Sandy, dolomitic limestone with a distinct purplish color. It is usually absent in the extreme eastern canyon, but where present, frequently occupies low areas on the disconformity above the Muav Limestone. The Temple Butte Limestone rarely is more than a few tens of feet thick and is the only formation which has been assigned to the Devonian System. The limestone contains few fossils: rare corals, brachiopods and gastropods.

Disconformity - A surface of unbelievable flatness, generally lacking even the minor channeling of the disconformity below the Temple Butte Limestone. No karst topography has been found. This disconformity overlies the Temple Butte Limestone and in places merges with the underlying disconformity where it rests directly on Muav Limestone. Is there evidence here of 100 million years of erosion occurring after the continent was uplifted out of the ocean? The lenticular infillings of Temple Butte limestone have not been found to contain stream gravels, and, so, are not the deposit expected for prolonged river erosion. Could this surface, instead, be explained by submarine removal of sediment by water currents?

Redwall Limestone - Very pure, fine to coarse grained limestone and dolomite--light gray in unweathered samples but stained red by seepage and coating of red clays from overlying shales. The limestone forms a prominent 500-foot cliff almost exactly midway in elevation between the Colorado River and the south rim at Grand Canyon Village. The Redwall Limestone averages less than one percent silicate minerals (clay and quartz). Certain levels are rich in chert and dolomite. Marine fossils of ribbed brachiopods, gastropods, foraminifera, crinoids and corals occur at certain levels. (The Redwall Limestone has been assigned to the Mississippian System.) The formation thickens toward the northwest into Nevada where it reaches a thickness of 800 feet, and thins eastward into New Mexico. Creationists might suppose that a source of pure calcium carbonate sediments to the west was introduced over the canyon at the same time the Flood waters became hot from the "fountains of the great deep." Coarse grained carbonate detritus (organic and inorganic) brought in by Flood waters would have mixed with directly precipitated fine grained calcite and dolomite from hot water. Chert may have also been deposited from hot water as a silica gel which rapidly lithified.

Four members have been recognized in the Redwall Limestone. Thicknesses given below are from along the Kaibab Trail. From top to bottom (youngest to oldest) the four members are:

Horseshoe Mesa Member - Very fine grained light olive gray, thin bedded limestone. Forms top of cliff. Thickness is 67 feet. Fossils rare.

Mooney Falls Member - Fine to coarse-grained, very thick bedded, light olive gray limestone with fossils of foraminifera and brachiopods. Some gray chert near top. Forms most massive cliff of the formation with a thickness of 245 feet.

Thunder Springs Member - Very fine grained pale yellowish brown dolomite alternating with gray chert. Contains fossil brachiopods, bryozoans and crinoids. Thickness is 90 feet.

Whitmore Wash Member - Fine grained pink to brown dolomite and coarse grained light olive gray limestone containing fossils of crinoids, horn corals, foraminifera and brachiopods. Thickness is 88 feet.

Disconformity above the Redwall Limestone - A slight degree of relief exists on top of the Redwall and broad channels as much as 200 feet deep occur. This surface of erosion is of considerable interest to both creationists and evolutionists. Evolutionists have supposed that very significant chemical weathering occurred on this surface which dissolved the top of the Redwall Limestone, producing a so-called "karst" feature which even includes, it is supposed, buried caves and solution deposits.

The evidence of buried and infilled caves is found at the top of the Redwall Limestone, which contains within it lenticular deposits of red siltstone, clays or chert breccia resembling the overlying Supai lithology. E. D. McKee and R. C. Gutshick assumed that this solution occurred between the time the Redwall and Supai were deposited. Other geologists have assumed the same. However, hundreds of solution and collapse structures (breccia pipes) occur in strata above the top of the Redwall Limestone in the Grand Canyon region. Many of the solution and collapse structures have filled horizontally, radiating solution drainage channels in the uppermost Redwall, but contain fragments of formations overlying the Supai. Many solution collapse structures have been mined for copper and uranium, and have been documented to contain breccia fragments of Coconino Sandstone and even Kaibab Limestone. Thus, we should conclude that significant solution of the Redwall Limestone occurred after the Grand Canyon strata were deposited. The evidence is meager for solution occurring in the time interval between Redwall and

Supai.

We might again ask ourselves if tens of millions of years of chemical weathering and erosion would leave so little evidence of solution obviously assignable to the boundary between Redwall and Supai. In many places it is difficult to exactly locate the disconformity, and it is hard to prove that it exists, especially where limestone overlies limestone. In some places, only a few inches of chert breccia can be found without any soil evidence. Channelized flow of water appears to have occurred as the waters of the Flood became very shallow and erosive. Most of the solution and infilling features appear to have formed after the Flood. Thus, it is conclusive that solution has occurred, but inconclusive as to when it occurred. Evidence of pre-Supai solution is doubtful.

Surprise Canyon Formation - Recently geologists have recognized some of the deposits directly overlying the disconformity above the Redwall as a new formation. It has been called the Surprise Canyon Formation and consists of dark red-brown siltstone, sandstone and conglomerate which is usually less than 10 feet thick. It is poorly exposed as a slope at the top of the Redwall cliff. More study needs to be conducted on this formation. It has been assigned to the uppermost Mississippian or lowermost Pennsylvanian Systems.

Supai Group - A sequence of four formations which have differing lithologies. From top to bottom (youngest to oldest), the four formations are given Indian names:

Esplanade Sandstone - Pale red sandstone and siltstone with cross-bedding indicating rapid accumulation from rapidly flowing ocean water. Evidences of marine deposition include lateral intertonguing to the west with marine limestone (Pakoon Limestone), gypsum beds within the sandstone, and fusulinids (a marine planktonic animal) which rarely are found as fossils in the sandstone. Assigned to Permian System. Forms ledge and cliff. Thickness is 275 feet.

Wescogame Formation - Alternating pale red sandstone and siltstone with occasional tracks of vertebrate animals. Sheetlike geometry of cross-bedded bodies argues for marine flooding, not river sedimentation. The formation is dominated by limestone in the extreme western canyon. Assigned to Pennsylvanian System. Forms slope 240 feet thick.

Manakacha Formation - Orange-red and brown sandstone and mudstone above shale with limestone with red chert (jasper) beds and nodules at base of formation. Assigned to the Pennsylvanian System. This cliff-forming unit is 340 feet thick.

Watahomigi Formation - Gray and red limestone with some red chert beds, sandstone and shale indicate ocean deposition. Assigned to the Pennsylvanian System. This slope forming unit is the thinnest Supai Group formation at 160 feet thick.

The four Supai Group formations total about 1,000 feet thick. The red shales, which are the source of stain to the surface of the Redwall, have been supposed in classical geologic theory to have oxidized iron weathered in a continental environment. However, the very uniformity of the red shales and sandstones over tremendous areas (without a local source area or channel system) argues against continental origin and for marine origin. Throughout its extent, the Supai Group is underlain by the Redwall Limestone which, because of its purity, is not an acceptable source of clay and sand. Furthermore, the marine limestones of the Manakacha and Watahomigi formations are interlayered with red sandstone and shale which cannot represent continental exposure. Thus we have evidence for marine deposition of red sand. The Supai limestones thicken toward the west into southern Nevada where they have been given formation status (called the Callville Limestone). Supai sandstones have water-deposited cross-bedding which consistently dips toward the south and southeast. This indicates a northerly source of sediment but it must be very far away. One geologist has suggeted the nearest source area was northern Utah and Wyoming. Tracks of small quadruped animals have been found in the Supai. The heterogeneous lithology of the Supai Group makes it distinguishable from homogeneous formations above and below it. Uniformitarian geologists might argue that the Supai Group represents an enormous delta deposited where a river entered the ocean, but the thin widespread units without evidence of much channelized sand argues against it. The origin of the red color stain to the grains of Supai sand is debated by geologists. Some creationists have supposed hot Flood waters may have oxidized the sand grains.

Hermit Shale - Alternating thin-bedded, red shale and siltstone is 300 feet thick containing amphibian or reptile footprints, syneresis cracks, and fossils of ferns. A five inch long wing of a dragonfly was found in the shale. The formation thickens westward into Nevada where the shale intertongues with limestone. Limestones are also found in the Hermit Shale near Sedona, 75 miles south of the canyon. Uniformitarian geologists recognize that water deposited the shale but suppose it accumulated in a continental enviroment such as a river floodplain or delta. But a river delta would also contain much sand, which the Hermit does not. Again, uniformitarians might suppose the red color came from oxidation of iron on a continent exposed to weathering, but no red sedimentary units are being deposited in modern river floodplains and deltas. Where did the red clay and silt come from? The underlying Esplanade Sandstone could not be the source as it has little clay and is not deeply channeled or eroded. A very distant source area must be supposed. The Hermit Shale has been assigned to the Permian System.

Paraconformity between Hermit and Coconino - The Hermit Shale has not been significantly channeled, and very little evidence exists for an extensive period of erosion between the Hermit Shale and the overlying Coconino Sandstone. It is with considerable interest that we note that 750 feet of sandstone, shale, and limestone (the Schnebly Hill Formation) occur between the Hermit Shale and the Coconino Sandstone at Sedona in central Arizona. In the uniformitarian way of thinking, the time break between Hermit and Coconino at the canyon might be assumed to represent tens of millions of years, yet we marvel at the flat and nearly conformable nature of the contact.

Coconino Sandstone - White or cream-colored quartz sandstone with enormous cross-bedded units sometimes 50 feet thick. Individual cross beds typically have dips averaging 25 degrees, containing footprint fossils of quadruped animals, probably reptiles. Because of its unique color and internal structure, the Coconino Sandstone is the most easily recognized formation in the canyon. At Grand Canyon Village, the Coconino is 300 feet thick but thickens to 1,000 feet, 100 miles south of the canyon. North of the canyon along the Utah border, and west of the canyon along the Nevada border, the Coconino Sandstone thins to zero. The area occupied by the Coconino is approximately 32,000 square miles, and its volume approximately 3,000 cubic miles. The cross beds dip consistently toward the south or southeast, indicating that sand came from the north or northwest, yet the underlying Supai and Redwall are as persistent as the Coconino and no angular unconformity below the Coconino is known, where the enormous quantity of sand could be derived. Evidently it came from a very great distance to the north.

Uniformitarian geologists have proposed that the Coconino sand was moved by wind from the north and that the enormous cross beds represent slip faces on the downwind (southern) slopes of desert sand dunes. However, it is difficult to imagine how reptiles could survive in the middle of an enormous desert. Because the vertebrate trackways show northward orientation (the animals walked up the slip face of the dunes), one geologist who assumed the desert model supposed the animals were heading to Utah to get a drink! The animal trackways often terminate abruptly, indicating that the animal simply swam away. The outline of the footprints more closely represents those made under water by amphibians and reptiles in the laboratory of Dr. Leonard Brand, a creationist. His extensive study was published in a uniformitarian journal. Furthermore, some of the cross beds have dip angles exceeding 34°, which may be a better analog with cross beds formed under water than with modern desert dune cross beds. Of all the sedimentary formations in the canyon, the Coconino Sandstone is the only one uniformitarians have proposed was deposited without water transport. However, study by creationists indicates that further research may verify that water was indeed responsible for depositing the sand. If the cross beds were deposited in water, the water would have had to be at least 100 feet deep, moving southward with considerable current velocity of approximately three feet per second. One finds it possible to visualize a water catastrophe on a scale of Noah's Flood forming the Coconino Sandstone. The Coconino Sandstone has been assigned to the Permian System.

Toroweap Formation - Gray fossiliferous limestone with considerable clastic impurities, particularly quartz sand. The Toroweap is about 250 feet thick, with the central 75 feet consisting of purer limestone with reddish, sandy limestone at the top and bottom. The Toroweap thins toward the east and becomes more sandy, becoming indistinguishable from the underlying Coconino Sandstone southeast of the canyon. The limestone becomes less sandy toward the west. Brachiopods are the most common fossils (especially Derbya, Meekella and productids). The sand in the Toroweap appears to have been eroded from the Coconino, suggesting that water currents, not a sluggish sea, were important in depositing the Toroweap. The fact that quartz sand grains are dispersed throughout the limestone argues that strong currents prevailed throughout deposition. The abrupt and flat contact with the Coconino, and what may be an intertonguing relationship, indicates no long period of time separated the two formations. The Toroweap has been assigned to the Permian System.

Kaibab Limestone - Light gray to cream colored, sandy and cherty limestone approximately 250 feet thick. The lower part is dolomitic limestone, the middle part is cherty limestone, and the upper part is dolomitic limestone with silty and sandy zones. The limestone contains marine fossils similar to those of the underlying Toroweap. The Kaibab, like the Toroweap, becomes richer in sand toward the east. Sixty miles east of the canyon, where the Toroweap Limestone is missing, the Kaibab Limestone rests on the Coconino Sandstone. Reddish zones in the upper Kaibab are caused by sandy siltstone. In the extreme eastern canyon, the upper part of the Kaibab Limestone contains cross-laminated sandstone with fossils indicating water current action, transported sand, and lime sediment. The Kaibab forms the rim rock and surface of the Coconino and Kaibab plateaus because it was overlain by very erodable shales of the Moenkopi Formation. The uppermost Kaibab Limestone does not occur at the rim, in contact with the overlying Moenkopi Formation.

Unconformity above Kaibab Limestone - A very poorly exposed erosion surface occurs in the Grand Canyon region between the Kaibab and Moenkopi. Erosion of the underlying Kaibab Limestone occurred in northeastern Arizona where Moenkopi shales sit directly on Coconino Sandstone and DeChelly Sandstone. Evidently the waters of the Flood became shallower and more erosive. This unconformity and others above it seem to mark a turning point in the Flood when the waters began to decrease generally in northern Arizona. The present erosion surface on top of the Kaibab Limestone, which forms many of the plateaus in the Grand Canyon area, was caused by later sheet-flood erosion as northern Arizona became exposed later in the Flood.

Moenkopi Formation - Strong evidence exists that the Kaibab Limestone, which forms the rim of the canyon, was overlain everywhere by the Moenkopi Formation, a red colored mudstone siltstone, and sandstone deposit almost 300 feet thick. The formation is very soft, and is often poorly exposed due to its ease of erosion. Erosionally isolated remnants of Moenkopi occur at Red Butte, south of Grand Canyon Village, and at Cedar Mountain, east of Desert View Tower. Thus, we suppose that Moenkopi originally overlaid Kaibab throughout the Grand Canyon region before erosion removed the Moenkopi. The middle of the unit contains gray to buff claystone, with lenses and veins of gypsum. The Moenkopi Formation is best exposed east of the canyon, as at Wupatki National Monument, 30 miles north of Flagstaff. The Moenkopi has been assigned to the Triassic System.

Chinle Formation -The top of Cedar Mountain, east of Desert View Tower, is capped by a resistant layer of conglomerate (the Shinarump Conglomerate Member of the Chinle Formation), which appears to be the erosional remnant of an enormously vast chert pebble and sandstone layer which can be found north, west, south and east of the canyon. The chert pebbles have no source known from underlying layers, and must have been transported by shallow, sheet flooding from a very distant source area. Forming the bulk of the Chinle Formation above the conglomerate are redish-purple and purple sandstones with gray, green, and brown shales and volcanic ash beds. A truly colossal quantity of volcanic ash (thousands of cubic miles) occurs in the Chinle. Logs from large trees, ferns, and dinosaur fossils have been found in the Chinle. The Petrified Forest National Park is famous for its petrified wood. The formation has been significantly eroded along with the underlying Moenkopi shales by the retreat of the Flood. The rolling, low topography of the Painted Desert is caused primarily by erosion of the Chinle Formation. The Chinle has been assigned to the Triassic System.

Landslide Deposits - Following the erosion of the Colorado Plateau and establishment of the canyon, landslides have been a dominant mode of cliff retreat. Many significant large landslide deposits are located in the eastern and western Grand Canyon. Landslides, no doubt, were more numerous in the past when slopes were significantly wetter and more unstable immediately after the Flood.

Western Grand Canyon Lava Flows - In the Toroweap area, on the north side of the Colorado River, volcanoes flooded large areas of plateaus with lava which cooled to form the rock called basalt. Some of these lava flows actually flowed over the north rim of the canyon, forming frozen lava falls descending to the river. Lavas appear to have blocked the river, forming large lakes which occupied the eastern canyon area. Breaching of these lava dams caused recent catastrophic erosion, especially in the inner gorge of the canyon. Many of these lava flows are attributed to the Pleistocene by geologists, but give anomalous radioactive isotope dates. These flows obviously post-date the erosion of the canyon and appear to be as fresh as any lava erupted from modern volcanoes just hundreds of years ago. Dr. Austin generated a rubidium-strontium isochron age of 1.5 billion years for these rocks, an age which is geologically ridiculous. This shows that radioactive isotope dating methods do not give reliable ages for rocks.

SELECTED REFERENCES ON STRATA OF THE GRAND CANYON

The following references reflect both creationist and evolutionist opinions on the Grand Canyon:

Akers, J. P., Irwin, J. H., Stevens, P. R., and McClymonds. N.E., 1962, Geology of the Cameron quadrangle, Arizona: U.S. Geological Survey, Geological Quadrangle Map, GC-162, scale 1:62,500. (Description of strata east of the Grand Canyon.)

Austin, S. A., 1984. Catastrophes in earth history: A source book of geologic evidence, speculation and theory: El Cajon, CA, Institute for Creation Research technical monograph No. 13, 318 p. (Contains plain English abstracts of geologic literature dealing with catastrophic processes and geologic products formed by catastrophic processes.)

Austin, S. A., 1988, Grand Canyon lava flows: a survey of isotope dating methods: Santee, CA, Institute for Creation Research, Impact No. 178, 4 p. (An evaluation of potassium-argon and rubidium-strontium methods for dating the Cardenas Lavas and the Western Grand Canyon Lava Flows.)

Barrington, J., and Kerr, P. F., 1963, Collapse features and silica plugs near Cameron, Arizona: Geological Society of America Bulletin, v. 74, p. 1237-1258. (Evidences for solution and collapse as the process responsible for forming mineralized breeccia pipes in limestones east of the Grand Canyon.)

Beus, S. S., and Rawson, R. R., 1979, Carboniferous stratigraphy in the Grand Canyon country northern Arizona and southern Nevada: American Geological Institute Selected Guidebook series no. 2, 138 p. (Collection of papers on the Redwall Limestone and Supai Group.)

Billingsley, G. H., Barnes, C. W., and Ulrich, G. E., 1985, Geologic map of the Coconino Point and Grandview Point quadrangles, Coconino County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map. I-1644, scale 1:62,500. (Description of strata and solution-collapse structures.)

Billingsley, G. H. and Beus, S. S., 1985, The Surprise Canyon Formation--an upper Mississippian and Lower Pennsylvanian (?) rock unit in the Grand Canyon, Arizona: U.S. Geological Survey Bulletin 1605-A, p. A27-A33. (Description of a new formation which had been previously considered to be part of the Redwall and Watahomigi Formations. Solution-collapse structures are described at the top of the Redwall.)

Blakey, R. C., 1984, Marine sand-wave complex in the Permian of central Arizona: Journal of Sedimentary Petrology, v. 54, p. 29-51. (Description of the Schnebly Hill Formation, which is between Hermit Shale and Coconino Sandstone in central Arizona.)

Bloeser, B., Schopf, J. W., Horodyski, R. J., and Breed, W. J., 1977, Chitinozoans from the late Precambrian Chuar Group of the Grand Canyon, Arizona: Science, v. 195, p. 676-679. (Description of flask-shaped microfossils from the Kwagunt Formation.)

Brand, L. R., 1978, Footprints in the Grand Canyon. Origins, v. 5, p. 64-82. (Creationist work on Coconino Sandstone footprints.)

Brand, L. R., 1979. Field and laboratory studies on the Coconino Sandstone (Permian) vertebrate footprints and their paleoecological implications: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 28, p. 25-38. (The character of Coconino Sandstone footprints most closely resembles tracks made underwater.)

Breed, W. J., and Road, E. C., eds., 1974. Geology of the Grand Canyon: Flagstaff, AZ, Museum of Northern Arizona and Grand Canyon Natural History Association, 186 p. (Basic geology of Grand Canyon from the uniformitarian viewpoint.)

Breed, W. J., Stefanic, V., and Billingsley, G. H., 1986, Geologic guide to the Bright Angel Trail: Tulsa, OK, American Association of Petroleum Geologists, 41 p. (Includes very detailed geologic map of Bright Angel Trail at scale 1:4800.)

Burdick, C. L., 1974. The Canyon of Canyons: Minneapolis, MN, Bible-Science Assoc., 78 p. (Creationist summary of the Grand Canyon, but already out of date.)

Chadwick, A. V., 1978. Megabreccias: evidence for catastrophism: Origins v. 5, p. 39-46. (Description of enormous boulders at the base of the Tapeats Sandstone with a clear statement on their relationship to catastrophism.)

Chadwick, A. V., 1981. Precambrian pollen in the Grand Canyon - A reexamination. Origins, v. 8, p. 7-12. (Questions C. L. Burdick's claim that the Hakati Shale contains pollen from pine trees.)

Elston, D. P., 1979, Late Precambrian Sixtymile Formation and orogeny at top of the Grand Canyon Supergroup, northern Arizona: U.S. Geological Survey Professional Paper 1092, 20 p. (Landslide deposits indicate that the Sixtymile Formation was deposited while the Chuar Syncline was being flexed. Catastrophism is supported by the data.)

Ford, T. D., and Breed, W. J., 1973. Late Precambrian Chuar Group, Grand Canyon, AZ. Geological Society of America Bull., v. 84, p. 1243-1260. (Describes 6,610 feet of strata in the eastern Grand Canyon.)

Garrett, W. E., 1978. The Grand Canyon: National Geographic Magazine, v. 154, p. 2-51. (Introduction to geography of Grand Canyon.)

Hamblin, W. K., and Rigby, J. K., 1968, Guidebook to the Colorado River, Part 1: Lee's Ferry to Phantom Ranch in Grand Canyon National Park: Brigham Young University Geology Studies, v. 15, p. 1-84. (River guide to Grand Canyon geology.)

Hereford, R., 1977. Deposition of the Tapeats Sandstone (Cambrian) in Central Arizona. Geological Society of America Bull., v. 88, p. 199-211. (Uniformitarian model for origin of Tapeats Sandstone.)

Huntoon, P. W., et al., 1980. Geologic map of the eastern part of the Grand Canyon National Park, Arizona: Grand Canyon, AZ, Grand Canyon Natural History Association, scale 1:62,500. (Recent geologic map of the eastern Grand Canyon.)

Kofford, M. E., 1969, The Orphan Mine: Four Corners Geological Society Guidebook, p. 190-194. (Solution and collapse structure forming a breccia pipe between the Coconino Sandstone and the Redwall Limestone located below Powell Point near Grand Canyon Village.)

Maxson, J. H., 1969, Preliminary geologic map of the Grand Canyon and vicinity, Arizona, western and central sections: Grand Canyon, Grand Canyon Natural History Association, scale 1:62,500.

McKee, E. D., 1975, The Supai Group, subdivision and nomenclature: U.S. Geological Survey Bulletin 1395-J, 11 p. (The Supai is raised to group status and divided into four formations.)

McKee, E. D., 1954, Stratigraphy and history of the Moenkopi Formation of Triassic age: Geological Society of America, Memoir 61, 133 p. (Description of this formation around the Grand Canyon.)

McKee, E. D., and Gutschick, R.C., 1969, History of the Redwall Limestone of northern Arizona: Geological Society of America Memoir 114, 726 p. (Description of the Redwall Limestone and some of the supposed "karst" features at the top of the Redwall.)

Moore, R. T., et al., 1960. Geologic Map of Coconino County, Arizona: Tucson, Arizona Bureau of Mines and University of Arizona, scale 1:375,000.

Potochnik, A. R., and Reynolds, S. J., 1986, Geology of side canyons of the Colorado, Grand Canyon National Park: Fieldnotes, Arizona Bureau of Geology and Mineral Technology, v. 16, no. 1, p. 1-8. (Summary of uniformitarian thinking on geology of selected side canyons.)

Rogers, J. D. and Pyles, M. R., 1980, Evidence of catastrophic erosional events in the Grand Canyon: Proceedings of the Second Conference on Scientific Research in National Parks, v. 5, p. 392-454. (Provides evidence for rapid breaching of lava dams in the western Grand Canyon and catastrophic drainage of lakes within the Grand Canyon.)

Shelton, J. S., 1966. Geology illustrated: San Francisco, W.H. Freeman, 434 p. (Summary of uniformitarian thinking on Grand Canyon strata.)

Stevenson, Gene M., and Stanley, B., 1982. Stratigraphy and depositional setting of the upper Precambrian Dox Formation in Grand Canyon. Geological Society of America Bull., v. 93, p. 163-173. (The Dox Sandstone is divided into four members.)

Stewart, J. H., Anderson, T. H., Haxel, G. B., Silver, L. T., and Wright, J. E., 1986, Lake Triassic paleogeography of the southern Cordillera: The problem of a source for voluminous volcanic detritus in the Chinle Formation of the Colorado Plateau region: Geology, v. 14, p. 567-570. (Three-fourths of the lower Chinle consists of about 17,000 cubic miles of volcanic detritus. The volcanic sources are not known.)

Waisgerber, W., Howe, G. F., Williams, E. L., 1987, Mississippian and Cambrian strata interbedding: 200 million years hiatus in question: Creation Research Society Quarterly, v. 23, p. 160-167. (Description of the paraconformity between Muav Limestone and Redwall Limestone on the North Kaibab Trail. Questions the supposed depositional hiatus of 200 million years between the formations.)

Wanless, H. R., 1981. Environments and dynamics of clastic sediment dispersal across Cambrian of the Grand Canyon. American Association of Petroleum Geologists Bull., v. 65, p. 1004-1005. (Alternate uniformitarian model for Tapeats Sandstone.)

Wilson, E. D., and Moore, R. T., 1959, Geologic map of Mohave County, Arizona: Tucson, Arizona Bureau of Mines and University of Arizona, scale 1:375,000.

Wood, W. H., 1966. Facies changes in the Cambrian Muav Limestone, Arizona, Geological Society of America Bull., v. 77, p. 1235-1246. (Description of horizontal and vertical changes in the Muav Limestone.)

GEOLOGY OF NORTHERN ARIZONA: A CREATIONIST SUMMARY

by Steven A. Austin, Ph.D.

Whether you drive, fly, float or walk in northern Arizona, you can train your eye during your travel to recognize a wide variety of geologic features. Creationists understand these to be a collosal monument to creation and the Flood. Our observations of both Scripture and the earth allow us to propose excellent agreement between the Word of God and the works of God.

NOAH'S FLOOD IN THE BIBLE

Noah's Flood was one of the truly great events in history. Four chapters of the Bible (Genesis 6-9) are concerned with this judgment upon the earth--more space than is offered to the account of the Creation (Genesis 1 and 2). What kind of flood was it? How has it changed the earth and life? Can the effects of Noah's Flood be seen in northern Arizona today?

The Extent of the Flood--The Bible says that the Flood covered ". . .all the high hills, that were under the whole heaven . . . ." (Genesis 7:19). This is clear language which describes a worldwide catastrophe which included northern Arizona.

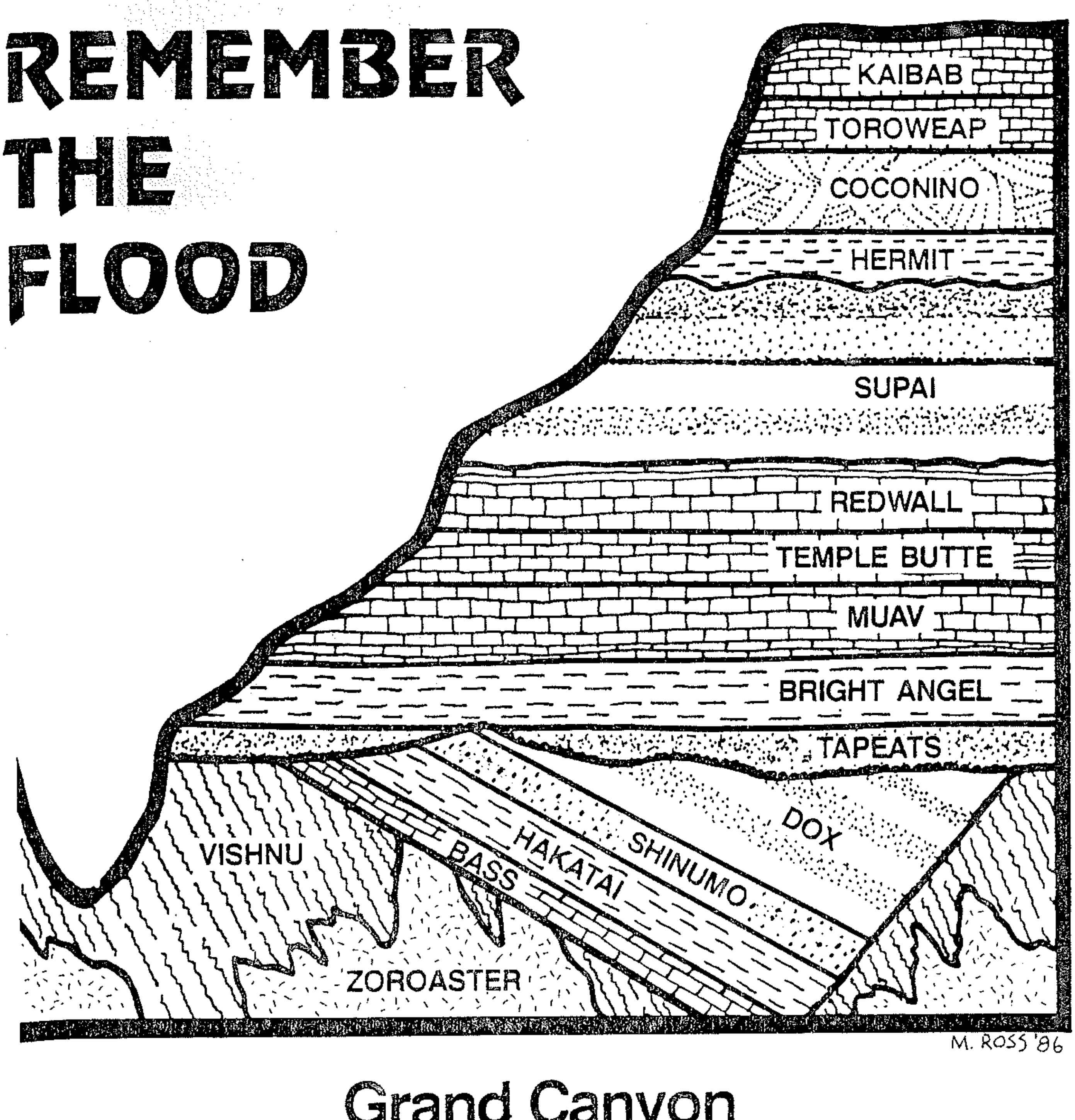
The Duration of the Flood--The Bible says that Noah's Flood was upon the earth 371 days (compare Genesis 7:11 and 8:14). The waters "prevailed upon the earth" for five months (Genesis 7:24) and took an additional seven months to subside. No modern local flood has had such long duration.

The Cause of the Flood--The Flood had a very unusual geologic cause in addition to the forty days of rain. Genesis 7:11 says that the "fountains of the great deep" were broken open. Evidently great earthquakes caused faulting on the sea floor, as subcrustal water and molten rock issued out of the earth.

The Effect of the Flood--The purpose of God in the Flood was as a judgment to destroy both man and the earth (Genesis 6:13). The Apostle Peter speaks of the Flood restructuring the entire surface of the earth: ". . . the world that then was, being overflowed with water, perished" (II Peter 3:6).

The Significance to Man--Only eight people survived the Flood with the animals on the ark (I Peter 3:20). After the Flood, God used the appearance of a rainbow in the sky as a sign of a covenant with man never to destroy the earth again by a global flood. That only eight survived is indicated by the universal nature of the rainbow covenant (Genesis 9:11-17) and the fact that almost every ancient culture from around the world has Flood traditions, many amazingly similar to the Bible's account. The Havasupai Indians, who today inhabit the Grand Canyon, have their own Flood legend explaining the formation of the land surface. The Biblical description is clearly the reliable account of the Flood, as it almost reads like the log book of Noah on the ark (see Genesis 7:1-8:19). Other Flood traditions appear to be corruptions of the true account, by inclusions of unbelievable circumstances and gross polytheistic themes.

REMEMBER THE FLOOD



Grand Canyon

WATER-DEPOSITED STRATA

Strata of northern Arizona show the agency of flood-water action on an enormous scale.

The Ocean was Over the Continents--Marine shell fossils compose limestone over 9,000 feet above sea level on the Kaibab Plateau, just north of Grand Canyon.

Rapid Burial--Fossil footprints, shell fossils, fossil logs, coal, large transported boulders, and general conformability of strata indicate catastrophic action, not long ages. The Chinle Formation at Petrified Forest National Park contains countless thousands of logs which were floated, buried, and fossilized.

Widespread Strata--The amazing horizontal continuity of strata argues against a local site for sedimentation (beach, river, or delta), but favors a widely acting agent. Supai sandstones, limestones, and shales are so continuous through the Grand Canyon that they cannot represent a river delta. Shinarump Conglomerate contains sand and pebbles distributed by sheet flooding over an area of 100 thousand square miles. Continuity of strata has been broken by faulting or erosion after strata were deposited.

Long Distance of Sediment Transport--Most of the materials that compose the strata did not come from local erosion and transportation of immediately underlying strata, but from distant erosion and interregional transport. Two thousand cubic miles of Coconino Sandstone, covering thirty thousand square miles of Arizona, could not be derived from erosion of underlying Hermit Shale. Supai shales and sandstones, which everywhere overlay Redwall Limestone, could not be derived from the limestone. Pebbles of red chert in the Shinarump Conglomerate have an unknown but very distant source area.

WATER-ERODED LANDSCAPE

Sculpture of the land surface was by Flood waters and by enlarged drainage following the Flood. Most landforms of northern Arizona are relict, left over from Flood and post-Flood erosion processes, not continuously forming by slow erosion that is occurring today.

The Great Unconformity--Advancing Flood waters scoured the pre-Flood surface of the earth to form the "Great Unconformity," a worldwide geologic feature. Strata above the Great Unconformity appear to represent the first Flood deposits.

Plateau Erosion--Sheet-like water erosion during retreat of Flood waters, removed thousands of feet of soft-sediment from the plateaus as they were uplifted. Kaibab Plateau and Coconino Plateau are remnants left over from the Flood, being slowly destroyed today by erosion.

Canyon Erosion--Channelized water flow during the latest retreat of the Flood and during the post-Flood time produced the main canyons eroded into the plateaus. Canyons, being deeper and wider than present streams require, are "underfit" relative to their streams. You can train yourself to recognize canyons formed by greatly increased discharge as you travel through the

Southwest. The Grand Canyon appears to have formed by catastrophic breaching of the uplifted plateau by water which was impounded east of the plateau.

Amphitheatre-headed Side Canyons--Slopes adjacent to main canyons usually failed by collapse of poorly consolidated, water-soaked sediment. The collapse formed short, bowl-shaped side canyons. These are not narrow and pointed, beginning at a gully as modern ravines excavated by slow-water erosion of solid rock.

Stained and Varnished Slopes--A red or brown coating of oxide or clay has been attaching itself to most rocks of the southwestern deserts. It shows that most slopes are not actively eroding, but are stagnant relief surfaces left over from ancient erosion. The Redwall Limestone of the Grand Canyon is naturally gray in color, but has been stained by an oxide coating released from the Supai shales above it. A brown coating called "desert varnish," covers most long-exposed rocks in the Southwest, showing that entire mountain ranges are relict features.

Cliffs without Talus--If slopes in the deserts of the Southwest have formed over millions of years as cliffs slowly retreated, a large buildup of blocks of cliff material should be seen at the base of most cliffs. Such a deposit is called talus. The small amount of talus at the base of most cliffs argues that cliffs are not slowly retreating, but, as shown by stains and varnishes, are themselves relict features.

EARTH-WRENCHING FORCES

Great stresses within the earth folded and faulted strata before, during, and after the Flood.

Precambrian Strata of the Grand Canyon--Faulted, tilted, and eroded pre-Flood strata are deeply buried in the Grand Canyon. The deepest of these strata were probably deposited during Creation Week, with most of the faulting and tilting representing early Flood upheaval of the earth.

East Kaibab Monocline--Intense flexure of strata was caused by uplift of Kaibab Plateau along a buried fault in the late stage of the Flood. Strata are not only faulted, but very intensely folded. The severe bending of strata argues that some strata remained in a soft condition during the uplift at the end of the Flood. Evolutionists who assume 400 million years between deposition and bending of strata have a problem explaining how the strata escaped being lithified by mineral cements.

Down-warped Basin--Subsidence of the Black Mesa area east of the Grand Canyon late in the Flood prevented strata in this area from being eroded. Over ten thousand feet of strata were deposited here by the Flood.

VOLCANOES

In response to earth-wrenching forces, molten rock deep in the earth forced its way upward as cracks opened in the crust of northern Arizona. Volcanoes formed where molten rock broke the earth's surface.

No.

Pre-Flood Volcanism--Among the deeply buried and diagonally tilted strata at the bottom of the Grand Canyon are ancient lava flows. These are called the Cardenas Lavas. Pre-Flood tectonic forces opened up cracks in the earth causing extensive layers of basalt to accumulate. The Cardenas Lavas appear to have been deposited in the years before the Flood began, or possibly date back to Day Three of Creation Week when the continents were uplifted.

Late Flood Volcanism--Strata deposited late in the Flood contain large amounts of volcanic ash derived from explosive volcanoes. The volcanic ash was redeposited by Flood waters. No local source of this volcanic ash is known. The Chinle Formation contains an estimated 17 thousand cubic miles of volcanic ash. The location of the source volcanoes is not known, but must have been extremely distant.

Post-Flood Volcanoes--San Francisco Peaks, near Flagstaff, and the western Grand Canyon lava flows in the Toroweap area, represent post-Flood volcanoes. The western Grand Canyon lava flows issued from vent areas on the north rim, and actually flowed over the north rim into the Grand Canyon forming gigantic "frozen" lava falls. Evidences of catastrophic post-Flood volcanoes are also found in widespread lava flows south of the Grand Canyon.

FOSSILS

Traces of once-living organisms are found in many strata in the Grand Canyon area. Most were pre-Flood organisms preserved by rapid burial in sediment during the Flood.

Abrupt Appearance of Fossil Types--No indisputable multicellular fossils have been found below the "Great Unconformity." Only one-celled algae fossils are known from what appear to be pre-Flood strata. Fossils in formations above the "Great Unconformity" are complex, fully formed organisms: trilobites, brachiopods, corals, dinosaurs, ferns, and conifers. The abrupt appearance of fossil types, without transitional forms, is what would be predicted on the basis of the creation model.

Marine Organisms Buried First--The advance of Flood waters brought in marine creatures which were buried first. The Grand Canyon strata (Tapeats Sandstone through Kaibab Limestone) are dominated by marine fossils.

Terrestrial Organisms Buried Last--The higher continental area were the last to be inundated with Flood waters. Terrestrial organisms with mobility (vertebrates) and floatability (trees) were the last to be buried. Their fossils are found in strata which have been eroded off the rim of the Grand Canyon. These strata and their fossils are found in the large down-warped basin at Black Mesa to the east of Grand Canyon.

SUGGESTED READINGS

Austin, Steven A., 1986, Did Noah's Flood cover the entire world? in Ronald Youngblood, ed., The Genesis debate: persistent questions about creation and the flood: New York, Thomas Nelson, p. 210-229. (Scientific and Scriptural reasons for a universal flood.)

Coffin, Harold G., 1983, Origin by design: Washington, D.C., Review and Herald, 494 p. (A creationist and catastrophist book summarizing a wide variety of geologic evidences for Noah's Flood).

Roth, Ariel A., 1986, Scientific evidence of a worldwide flood: Signs of the Times, v. 113, no. 1, p. 8-11, 20, 21. (Concise yet scholarly defense of geologic evidences for Noah's Flood.)

Whitcomb, John C., Jr., 1973, The world that perished: Winona Lake, IN, BMH Books, 155 p. (A brief sequel to The Genesis Flood by one of its coauthors, with answers to published critical reviews of that book with additional evidences supporting Noah's Flood.)

TEN MISCONCEPTIONS ABOUT THE GEOLOGIC COLUMN

by Steven A. Austin

The ten strata systems that geologists use (Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and Tertiary) compose the "standard geologic column" and are claimed by many to contain the major proof of evolutionary theory. Several erroneous notions have been attached to the geologic column. The following are the ten most common misconceptions.

Misconception No. 1. The geologic column was constructed by geologists who, because of the weight of the evidence that they had found, were convinced of the truth of uniformitarian theory and organic evolution.

It may sound surprising, but the standard geologic column was devised before 1860 by catastrophists who were creationists.[1] Adam Sedgewick, Roderick Murchison, William Coneybeare, and others affirmed that the earth was formed largely by catastrophic processes, and that the earth and life were created. These men stood for careful empirical science and were not compelled to believe evolutionary speculation or side with uniformitarian theory. Although most would be called "progressive creationists" in today's terminology, they would not be pleased to see all the evolutionary baggage that has been loaded onto their classification of strata.

Misconception No. 2. Geologists composed the geologic column by assembling the "periods" and "eras" which they had recognized.

The geologic column was not composed by assembling a chronology of "periods," "eras" or other supposed measures of time, but by superposition of objectively defined sequences of sedimentary strata called "systems." The "periods" and "eras" were later appended to the system nomenclature of the "geologic column" transforming it into a "geologic time scale."

Misconception No. 3. The strata systems of the geologic column are worldwide in their occurrence with each strata system being present below any point on the earth's surface.

The notion that the earth's crust has on "onion skin" structure with successive layers containing all strata systems distributed on a global scale is not according to the facts. Data from continents and ocean basins show that the ten systems are poorly represented on a global scale: approximately 77% of the earth's surface area on land and under the sea has seven or more (70% or more) of the strata systems missing beneath; 94% of the earth's surface has three or more systems missing beneath; and an estimated 99.6% has at least one missing system.[2] Only a few locations on earth (about 0.4% of its area) has been described with the succession of the ten systems beneath (west Nepal, west Bolivia, and central Poland). Even where the ten systems may be present, geologists recognize individual systems to be incomplete. The entire geologic column, composed of complete strata systems, exists only in the diagrams drawn by geologists!

Misconception No. 4. Strata systems always occur in the order required by the geologic column.

Hundreds of locations are known where the order of the systems identified by geologists does not match the order of the geologic column. Strata systems are believed in some places to be inverted, repeated, or inserted where they do not belong. Overturning, overthrust faulting, or landsliding are frequently maintained as disrupting the order. In some locations such structural changes can be supported by physical evidence, while elsewhere physical evidence of the disruption may be lacking and special pleading may be required using fossils or radiometric dating.

Misconception No. 5. Because each strata system has distinctive lithologic composition, a newly discovered stratum can be assigned easily to its correct position in the geologic column.

Sandstone, limestone, dolomite, shale, chert, salt, conglomerate, coal and other rock types are not diagnostic of specific strata systems. Therefore, a rock's physical appearance cannot, with certainty, distinguish the system or strata level to which a rock may belong. The sequence of rock types is more useful but hardly an infallible guide to correlation. Thus, the Cambrian System on an intercontinental scale is typically composed of quartzose sandstone, overlain by glauconitic sandstone with dark-brown shale, overlain by impure, light-brown limestone.[3] The correlation of "Cambrian" strata is further strengthened by the presence on an intercontinental scale of an unconformity (surface of erosion) at or near the base of the system. Each rock type is not distinctive of the Cambrian, and neither is the unconformity, but the sequence may be.

Misconception No. 6. Fossils, especially the species distinctive of specific systems, provide the most reliable method of assigning strata to their level in the geologic column.

Bed-to-bed correlation of strata to their "type system" area is the most reliable method of assigning strata to a system. The data from oil well drilling, seismic surveys, and surface geologic mapping is of such character that subsurface correlation of lithostratigraphic units of the thickness of systems is possible on a continental scale. Although some fossils appear to be distinctive of certain systems (most fossil taxa range through a few to several systems), care must be exercised in correlation by fossils. First, the stratigraphic range of a fossil type is always open to extension as new fossils are discovered. Second, when an extension of a fossil's range may be required, geologists may call upon erosion (reworking fossils into younger strata or leaking fossils into older strata) and structural events (overturning or faulting strata and fossils). An example of the first problem is the monoplacophoran mollusk Pilina, which might otherwise be considered diagnostic of the Silurian System, except for the startling discovery that Neopilina lives today, and therefore, would be expected in any system overlying the Silurian. For these reasons correlation by fossils must always remain tentative awaiting further confirmatory evidence from lithostratigraphy. We should look skeptically at strata correlations which rely solely on fossils.

Misconception No. 7. Sedimentary evidence proves that periods of millions of years duration were required to deposit individual strata systems.

Before radiometric dating was devised, uniformitarian geologists postualted "periods" of millions of years duration to slowly deposit the strata systems. A single sedimentary lamina, or bed, was supposed by uniformitarian geologists to represent typically a year or many years duration. It was concluded, therefore, that multiplied thousands of laminae and beds superimposed required millions of years. Recently, however, geologists have discovered that laminae and beds form quickly on floodplains of rivers during floods, in shallow marine areas during storms, and in deep water by turbidity currents. The evidence of rapid sedimentation is now so easily recognized that geologists observing a strata system these days often ask where to insert the "missing time" of which the strata do not show sedimentary evidence. Catastrophism, quite naturally, is making a come-back. There is good reason to believe that entire strata systems, and even groups of systems, were accumulated rapidly.[4] The evidence allows for a hydraulic cataclysm matching Noah's Flood in the Bible.

Misconception No. 8. Radiometric dating can suply "absolute ages" in millions of years with certainty to systems of geologic column.

Geologists and geochronologists assert that radiometric dating verifies that individual strata systems and their strata are millions of years old. When asked to document the most reliable radiometric age dates, geologists usually point to isochron and concordia plots which employ multiple isotopic analyses, which they claim will remove the effects of original "contaminants," and display the "age" of a rock in graphical form. However, we find geologists often reporting isochron plots which are discordant with the accepted "ages" of strata systems.[5] Frequently these discordant isochron plots "date" strata systems much older than even the accepted old ages customarily assigned to the systems of the geologic column. Geologists should be asking which, if any, of the isochron plots should be accepted as "absolute ages," and if the discordances do not falsify the assumptions upon which radiometric dating is based. Geologists need to consider radiometric methods which indicate ages of thousands of years for strata systems,[6] as well as general indicators supporting young age.

Misconception No. 9. The environmental "pictures" assigned to certain portions of the geologic column allow us to accurately visualize what its "geologic ages" were like.

Books, films and museum displays contain illustrations asking us to visualize what earlier "geologic ages" were like. These "pictures" show supposed primitive earth conditions, specific environments with sediments being slowly deposited, inferred "transitional organisms" evolving toward familiar forms, and whole communities of organisms "at home" with other organisms absent. Perhaps the most blatant environmental "picture" has been assigned to lower Precambrian strata, formed when the earth supposedly had a reducing atmosphere and an "organic soup" in which life evolved. Yet geologists have yet to find sedimentary evidence for the reducing atmosphere and the soup.[7] This reminds us that accepting an environmental "picture" requires much imagination from a meager supply of facts.

Misconception No. 10. The geologic column and the positions of fossils within the geologic column provide proof of amoeba-to-man evolution.

All the animal phyla, including chordate fish, are now known as fossils in the Cambrian System.[8] No ancestral forms can be found for the protozoans, arthropods, brachiopods, mollusks, bryozoans, coelenterates, sponges, annelids, echinoderms or chordates. These phyla appear in the fossil record fully formed and distinct, in better agreement with the concept of "multiple, abrupt beginnings" (creation) than with the notion of "descent from a common ancestor" (evolution).

REFERENCES

1. R. Ritland, 1982, Historical development of the current understanding of the geologic column: part II: Origins, v. 9, pp. 28-47.

2. Estimated by the author using data from J. Woodmorappe, 1981, The essential nonexistence of the evolutionary-uniformitarian geologic column: a quantitative assessment: Creation Research Society Quarterly, v. 18, p. 46-71.

3. D. V. Ager, 1981, The nature of the stratigraphical record: New York, John Wiley, 2nd ed., p. 11.

4. S. A. Austin and J. D. Morris, 1986, Tight folds and clastic dikes as evidence for rapid deposition and deformation of two very thick stratigraphic sequences: Proceedings of the First International Conference on Creationism, Pittsburgh, Creation Science Fellowship, v. 2, p. 3-15.

5. C. Brooks, D. E. James, and S. R. Hart, 1976, Ancient lithosphere: its role in young continental volcanism: Science, v. 193, p. 1086-1094. S. A. Austin, 1988, Grand Canyon lava flows: a survey of isotope dating methods: Institute for Creation Research, Impact No. 178, 4 p.

6. R. V. Gentry, et al., 1976, Radiohalos in coalified wood: new evidence relating to the time of uranium introduction and coalification," Science, v. 194, p. 315-318.

7. S. A. Austin, 1982, Did the early earth have a reducing atmosphere?: Institute for Creation Research, Impact No. 109, July 1982, 4 p.

8. J. E. Repetski, 1978, A fish from the Upper Cambrian of North America: Science, v. 200, p. 529-531.

WHAT DOES "CAMBRIAN" MEAN?

by David R. McQueen

As treated elsewhere in Dr. Austin's article "Ten Misconceptions About the Geologic Column," many misunderstandings have arisen over the nature of the geological column. About a dozen words are currently in use by evolutionists to describe geologic time and the geologic age system. In the Grand Canyon, five words are commonly used to name over 80% of the Grand Canyon's rock strata: Precambrian, Cambrian, Mississippian, Pennsylvanian, and Permian. Let us look at one word, "Cambrian," to see how a Flood geologist would apply its historical meaning to a proper current context.

A British Christian named Adam Sedgwick was the one who coined the term "Cambrian." The Reverend Adam Sedgwick (1785-1873) was professor of geology at Cambridge University in England whose training was in theology but whose chosen field of study was geology. In his thesis work, ICR graduate student Jeff Jones has concluded that during the 1830's Sedgwick had embraced a "harmonization theory" of Genesis to account for geologic ages by a "gap theory." He was not, therefore, a Flood geologist in the ICR sense, but he did believe in geologic catastrophism.

It is important to understand that most students of the earth in Sedgwick's day believed that earth processes had operated on occasions in the past at a rate, scale and intensity far greater than they had observed in the North Sea, at the Cliffs of Dover, or on the beaches of Normandy. Professor Sedgwick wrote about the leading proponent of the contrasting view of uniformitarianism, Charles Lyell, in the following elegant 19th century prose:

> Mr. Lyell will admit no greater paroxysms than we ourselves have witnessed--no periods of feverish spasmodic energy during which the very framework of nature has been torn asunder. The utmost movement that he allows are a slight quivering of her muscular integuments. (From Sedgwick, Adam, 1831, Address to the Geological Society [18 Feb. 1831]: Geological Society of London, Proceedings, Vol. I [1826-1833], p. 281-316.)

Lyell's uniformitarianism has dominated geology ever since about 1850. In contrast to Lyell and other geological theorists, Sedgwick and other empiricists like him were noted as consumate field geologists. They studied the rocks with care, noting actual field relationships and sequence. In this vein we turn to sandstone and shale strata in Wales in southwestern England which Sedgwick and his students must have studied each school year in the 1820's.

The "Cambrian" rocks of Wales are marine sedimentary rocks. In the 1960's the common definition of "Cambrian" read (Webster's 7th New Collegiate Dictionary, 1965):

> (ML Cambria Wales) 1. WELSH 2. of, relating to, or being the earliest geologic period of the Paleozoic Era or the corresponding system of rocks marked by fossils of every great animal type except the vertebrate and scarcely recognizeable plant fossils.

We now have found vertebrate fish fossils in the Cambrian of the American west. Profesor Sedgwick did not consider the Paleozoic Era to have begun about 600 million years ago, as modern geologists do. He did not see the Welsh rocks as an indicator of slow, uniform processes of sedimentation and lithification as Lyell was proposing. He did not even consider them to be evidence of evolution, since he believed in Special Creation. There was a lot of baggage added to his term. How, then, did he use his own word "Cambrian?"

Imagine this scene set in the 1830's in Professor Sedgwick's Cambridge University geology class. The professor draws on the board a cross-section of the sandstone and shale strata the class is to visit when they take the train to Wales for a field trip. So as a practical teaching tool, Sedgwick names this sequence of rocks "Cambrian" instead of constantly referring to them as "those sedimentary rocks near Stonehenge in England, the district the Romans had called Cambria."

He did not name them Cambrian because he believed evolution to be true. It was simply a practical teaching tool for him to refer to them by their geographic location. Also, imagine what happened when his students went all over the then world-wide British Empire. These young geologists found just above the "Precambrian" rocks of their area, a sequence of layered sandstones and shales with trilobites which reminded them of what their "old Prof" had shown them in Wales. So at the height of the Victorian British Empire, "the sun never set" on the propagation and proliferation of the word "Cambrian." It was later absorbed into evolutionary speculations and terminology and has been with us ever since. Our ICR Flood geology team will be using "Cambrian" in Sedgwick's original sense of a group of rocks (predominately sandstone and shale strata) with a certain type of fossil (trilobites) which is at a certain position (as the first group of widespread strata) in the sequence of rocks above the Great Unconformity. We encourage you not to attach all the unnecessary baggage to the term as evolutionists do.

GLOSSARY OF GEOLOGIC TERMS

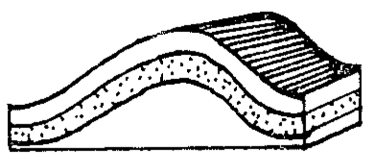
by Steven A. Austin

Selected basic geologic terms, except those relating to the geologic system nomenclature and minerals, are given below in alphabetical order. These terms are useful in describing features in the Grand Canyon. Words shown as **bold type** are defined in this glossary.

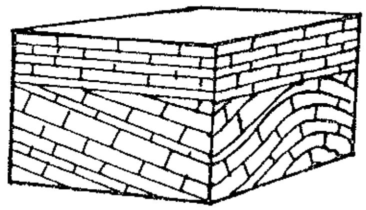
Amphitheater-headed canyon - A steep-sided valley with a wide upper end (head), not a narrow upper end beginning in a **gully**. The Grand Canyon's side canyons are often amphitheater-headed and are believed to have formed by the process of **sapping**.

Andesite - A fine-grained **igneous rock** composed of the minerals amphibole (25% to 40%), biotite and plagioclase, but no quartz or orthoclase. It forms from **lava** flows (probably derived from fractionation of partially melted basaltic material) and is a common volcanic rock in mountains bordering the Pacific Ocean. San Francisco Peaks south of Grand Canyon is built from andesitic flows.

Anticline - A fold structure in which the strata flex in two directions dipping away from the fold. Compare with **syncline** and **monocline**.



Angular unconformity - An **erosion** surface which has older strata below dipping at different (usually steeper) angle than the younger strata above. Compare to **unconformity, disconformity, nonconformity** and **paraconformity**.



Basalt - A dark-colored, fine-grained igneous rock composed of plagioclase feldspar (greater than 50%) and pyroxene. The mineral olivine may or may not be present. Basalt forms from **lava** flows and with andesite represents 98% of all volcanic rocks. The Precambrian Cardenas Lavas of the Grand Canyon contain basalt flows.

Bed - A layer of sediment which is greater than 1 centimeter thick. (Compare with **lamina**.)

Bedding plane - The surface forming the boundary between two successive layers of **sedimentary rock**. A bedding plane may show a **fossil**, **ripple marks** or **syneresis cracks**.

Boulder - A rock fragment whose diameter is more than 25.6 centimeters (10 inches). This rock fragment is bigger than a **cobble**, or bigger than a standard volleyball.

Breccia - Sediment or **sedimentary rock** composed of large angular fragments in a matrix of finer particles. Four types are recognized: sedimentary breccia, volcanic breccia, fault breccia, and impact breccia. If the fragments are well rounded the rock is called **conglomerate.**

Butte - An isolated hill usually capped by a flat-lying resistant layer of rock. A butte is the erosional remnant of more extensive strata.

Catastrophism - The doctrine that ancient geologic changes occurred largely in response to rapid and catastrophic processes which were interposed between periods of slow and gradual change. Compare to **uniformitarianism.**

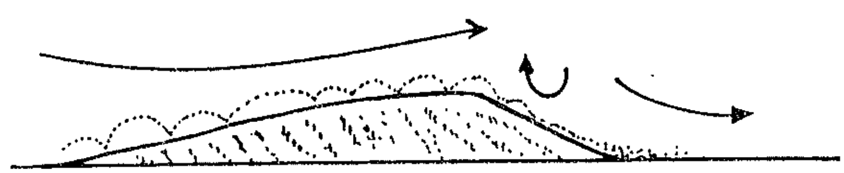
Cement - Minerals which have precipitated in between the grains of sedimentary rocks which bind the individual particles together.

Clay - Sedimentary material composed of very small particles less than 1/256 millimeter in diameter. Clay minerals are chiefly hydrous aluminum silicates weathered from feldspar, pyroxene or amphibole. A clay particle is smaller than **silt.**

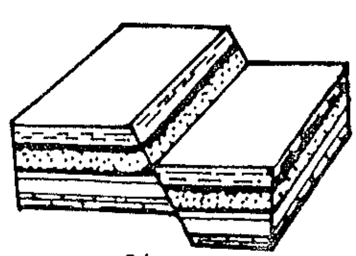
Cobble - A rock fragment with diameter between 64 millimeters and 256 millimeters (tennis ball to volleyball size). A cobble is larger than a **pebble** but smaller than a **boulder.**

Conglomerate - A **sedimentary rock** composed of rounded fragments of **pebbles, cobbles** or **boulders.** If the fragments are angular, the rock would be called **breccia.**

Cross-bedding - A type of **stratification** sometimes produced with deposited sand which is inclined from the original horizontal surface on which the sandy sediment was accumulated. It is produced by deposition of **sand** on the down-current slope of a desert dune or subaqueous sand wave. Cross-bedding is common in the Coconino Sandstone.



Cross-cutting relationships, Principle of - Any feature which breaks the continuity of structure or cross-cuts strata must postdate the structure or strata. Canyons, faults, impact craters and related features postdate the rocks containing them. A **fault** buried beneath an **unconformity** is older than the **unconformity.** This principle gives sequence in time, not absolute age or duration.

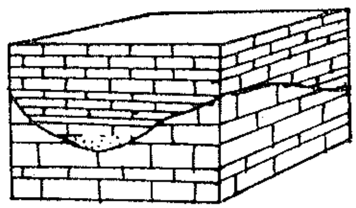


Desert varnish - Darkened chemical coating covering the surface of a rock in the desert. Although the interior of the rock may be light colored, the hard, sometimes shiny, coating of brown to black manganese oxide and clay minerals is built up or deposited on the rock surface over hundreds of years. **Desert varnish** indicates long period of stability, not continuous slow erosion. It is useful in spotting **relict** landforms.

Diabase - A type of igneous **intrusive rock** with composition similar to **basalt.**

Dike - A tabular body of **intrusive rock** that cuts across the structural features (e.g., **stratification**) of the surrounding rock. Contrast to **sill.** Dikes of Zoroaster Granite penetrate the Vishnu Schist in the Inner Gorge of the Grand Canyon.

Disconformity - A type of **unconformity** where **erosion** has occurred on a surface between strata which are parallel above and below the surface. Compare to **unconformity, angular unconformity, nonconformity,** and **paraconformity.**



Dolomite - A **sedimentary rock** composed mainly of calcium magnesium carbonate. Also the name of the **mineral** with the same composition.

Erosion - A large group of processes that loosen or remove sediment and transport it from one place on the earth's surface to another. Water, ice, wind and gravity are important agents of **erosion.**

Extrusive rock - **Igneous rock** which in a fluid state was accumulated on the earth's surface. Compare to **Intrusive rock.**

Fault - A surface within the earth along which breakage and displacement of rock has occurred.

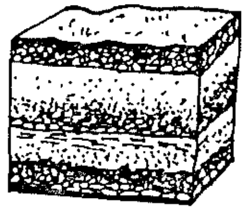
Formation - A body of rock strata which has distinctive character for study and mapping. Two or more **formations** are called a **group.** A division of a **formation** is a **member.**

Fossil - A naturally occurring remain or evidence of ancient life. Examples include bones, shells, impressions and trails.

Geologic **cross section** - A drawing depicting the structure and arrangement of rocks as they would appear in a vertical plane below the surface of the earth.

Gneiss - A **metamorphic rock** possessing alignment of light-colored and dark-colored minerals into distinct layers.

Graded bedding - A type of bedding in sedimentary deposits in which each layer possess a decrease in grain size from the bottom to the top of the bed.



Granite - A coarse grained crystalline rock which is composed of orthoclase (K-feldspar), plagioclase, quartz and small amounts of ferromagnesian minerals (usually biotite).

Group - A geological map unit consisting of two or more **formations.**

Gully - A very narrow valley worn in the earth by running water confined to a channel. Contrast with **amphitheater-headed canyon.**

Igneous rock - Rock which has formed from cooling and solidification of molten material. These rocks form by cooling of **lava** or **magma.**

Intrusive rock - **Igneous rock** which penetrated across or between other rocks while in a fluid state and solidified. Compare to **extrusive rock.**

Lamina - A layer of sediment less than 1 centimeter thick. The plural of **lamina** is **laminae.**

Lava - Molten rock which has reached the earth's surface.

Limestone - A **sedimentary rock** composed mainly of calcium carbonate.

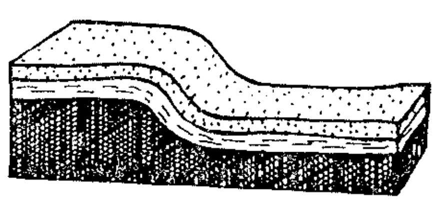
Magma - A molten mobil mass of silicate material which is contained within the earth.

Member - A division of a **formation**, generally of distinctive lithologic composition.

Metamorphic rock - A rock which has been reformed from preexisting rocks by the application of temperature and pressure and by gain or loss of chemical components by the chemical action of fluids.

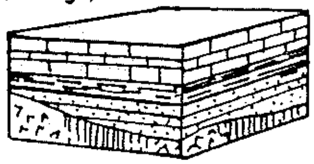
Mineral - Naturally occurring substances with definite crystal structure, fixed chemical composition (or varying over small range), and diagnostic physical properties.

Monocline - A fold structure in gently dipping strata in which the strata flex in only one direction from the horizontal. Compare with **syncline** and **anticline.** The East Kaibab Monocline in the extreme eastern Grand Canyon forms a north-south trending structure that elevates strata on the west by almost 3,000 feet forming the Kaibab and Coconino plateaus.



Mud crack - A specific type of crack occurring in a layer of clay, mud or silt that resulted from the contraction accompanied by drying. Compare with **syneresis crack. Mud cracks** in the Hermit Shale are claimed to indicate long time periods of sediment drying by uniformitarians, but the features may be **syneresis cracks** instead.

Nonconformity - A type of **unconformity** in which stratified rocks rest upon eroded metamorphic or igneous rocks. Compare with **unconformity, angular unconformity, disconformity**, and **paraconformity.**

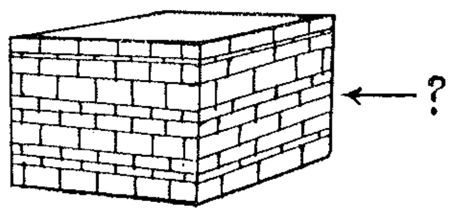


Original continuity, Principle of - Strata continue in all directions until ending by thinning or being blocked by an obstruction.

Original horizontality, Principle of - Strata were originally deposited horizontally (or very nearly horizontal) with tilting being subsequent to deposition. Deviations from true horizontality include **cross-bedding** in dunes, deposits on point bars in rivers, and accumulation of air fall tuffs on slopes.

Paleontology - The study of ancient life.

Paraconformity - An obscure or uncertain **erosion** surface buried in the earth in which no erosion surface is able to be seen or in which the contact is a simple bedding plane where the beds above and below the suspected break are parallel. Uniformitarian geologists often use this term to admit that evidence of long ages of erosion between rock strata layers is missing. It should be thought of a special type of **disconformity.** Compare to **unconformity, angular unconformity,** and **nonconformity.**



Pebble - A rock fragment with diameter between 2 millimeters and 64 millimeters (match head to tennis ball size). A **pebble** is larger than **sand** but smaller than a **cobble.**

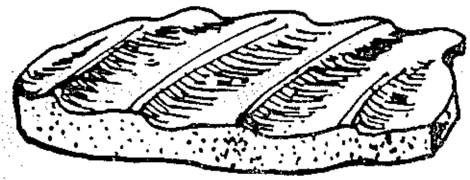
Plateau - A broad and extensive upland area which is considerably elevated above the adjacent country.

Quartzite - Metamorphosed **sandstone.**

Relict - Any landform which has survived decay and disintegration being left behind after disappearance or greatly reduced activity of the formative agent. A **plateau** and an **underfit valley** are examples of landforms often considered relict.

Relief - The difference in elevation between the low and high portions of a landscape area.

Ripple marks - Small ridges produced on the surface of **sand** or **silt** by the movement of water current or wind. When the ripple marks are asymetrical, the steeper side is the down-current side indicating direction of flow.

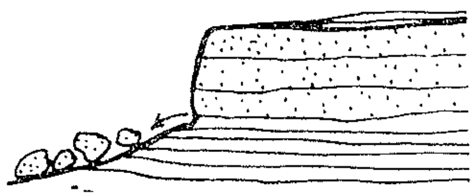


Rock - An aggregation of **minerals** or minerallike materials.

Sand - A rock particle whose diameter ranges from 0.0625 to 2 millimeters. Quartz grains are important components of sand because of their abundance and resistance to chemical and mechanical disintegration. These particles are larger than **silt** but smaller than a **pebble**.

Sandstone - A clastic **sedimentary rock** composed of **sand**-sized particles.

Sapping - A natural process of erosion at the base of a cliff by the removal of softer layers and the removal of support and breakage of large masses above from the cliff face. Sapping can be accelerated where water seeps from sediment or rock.



Schist - A coarse-grained **metamorphic rock** with parallel orientation of platy minerals (mica, chlorite or talc) without obvious segregation of light-colored and dark-colored minerals into layers as in **gneiss**.

Sedimentary rock - Rock formed by the accumulation and cementation of sediment. Usually these rocks form from transported mineral grains, but also by chemical precipitation at the depositional site.

Shale - A clastic **sedimentary rock** composed of **clay**-sized particles.

Sill - A tabular body of **intrusive rock** that penetrates between layers of the enclosing rock without cutting across the layers. Contrast to **dike**.

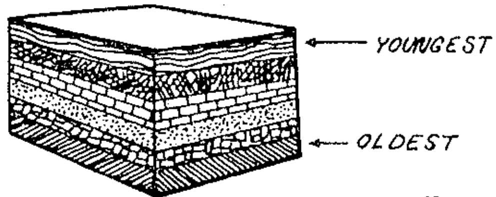
Silt - Rock particles whose diameters range from 1/256 to 1/16 millimeter. These particles are larger than **clay** but smaller than **sand**.

Siltstone - A clastic **sedimentary rock** composed of **silt**-sized particles.

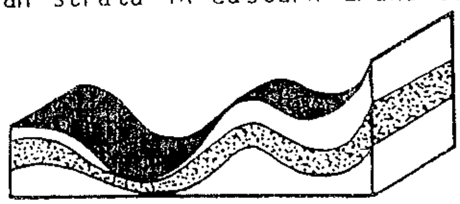
Stratification - The property of **sedimentary rocks** and volcanic rocks where layered structure occurs.

Stratum - A layer of sediment or **sedimentary rock**. A **bed** is thicker than 1 centimeter and a **lamina** is thinner than 1 centimeter. The plural of **stratum** is **strata**.

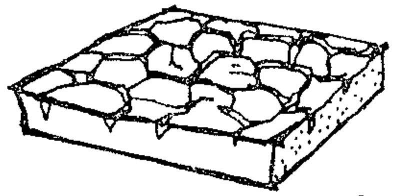
Superposition, Principle of - The principle that in any undisturbed succession of strata the oldest is at the base and the youngest is at the top.



Syncline - A fold structure in which the strata flex in two directions dipping toward the fold. Compare with **monocline** and **anticline**. The Precambrian strata in eastern Grand Canyon form a buried syncline.



Syneresis crack - The general name for a shrinkage crack occurring in a layer of **clay** or **silt** that resulted from contraction caused by spontaneous throwing off of water. Syneresis cracks can form under air by drying (see **mud crack**), under water by spontaneous dewatering, or within buried sediment layers by compaction and dewatering.



Talus - Broken rock fragments that accumulate as a sloping pile at the base of a cliff.

Texture - The size, shape, orientation, and packing of particles that compose a rock.

Topography - The form of the earth's surface. Topography is conveniently expressed as contour lines on certain types of maps.

Unconformity - The general name given to a major surface of **erosion** that has been buried within the earth under sediments or strata. Specific types are **angular unconformity**, **disconformity**, **paraconformity**, and **nonconformity**.

Underfit valley - A valley which previously had a large amount of water flowing through it, but now has a stream of greatly reduced size.

Uniformitarianism - The doctrine that ancient geologic changes occurred largely in response to slow and gradual processes without significant periods of rapid and catastrophic change. Compare to **catastrophism**.

FOSSILS OF THE GRAND CANYON

By Walt Barnhart and Duane Gish

In the Grand Canyon you will have an exceptionally good opportunity to view fossils of all types. By very careful observation fossils can be spotted in many of the major rock strata. The following article is an effort to help you know what you will see and where, so you will be better prepared to see it. Only one rule with the fossils you find: look, and take pictures if you like, for pictures are all you will take out.

Fossils, what are they?

A fossil is a relic of something that is past. Inoganic structures may leave fossils. For example, mica layers in the Tapeats Sandstone and Bright Angel Shale show fossil precipitation layers (called bedding planes). Ripple marks and mud cracks are fossil evidence of conditions when the rock material was buried. These are fossils of interest to the geologist, but here we are interested in fossils of creatures that were once living.

The fossils we will find are of interest to us because of what we can learn from them. Fossils may give us distinct ideas of what life forms lived together, the conditions in which they lived, and the circumstances which resulted in their burial.

Organic fossils, what we usually mean by the word fossil, are formed when living material is quickly buried under conditions where the organic material is not allowed to be dissipated by the natural processes of decomposition. Because certain parts of plants and animals are more durable--trunks of trees, hard seeds, bones, teeth, and hard shells of sea life--we expect to see them more often. This is only partly true. The bus tour will visit the petrified forest where many tree trunks of exceptionally large redwoods have been fossilized and preserved. There also have been a few dinosaur bones found. But here in the Canyon and its immediate vicinity, no bone or teeth material have been found. Fossilized shells of mollusks, gastropods, and brachiopods do occur very commonly through most of the layers.

It is amazing that many of the fossils which we can find in the Grand Canyon are of the much less substantial type, many of them of the type which would normally stand little or no chance of preservation in our modern world.

Specifically, four types of fossils are to be found.

1. **Chemical alteration** -- Sometimes living materials, plants or animals are buried in great quantity and are then chemically altered to form coal or oil. For many years evolutionists have contended that coal and oil could only be formed over extremely long periods of time but scientists in recent years have been able to produce them in the laboratory over relatively short periods of time under the proper conditions of temperature and pressure. With the explosion of Mt. St. Helens in recent years and the natural damming of Spirit Lake, our own Dr. Austin has had a unique opportunity to study conditions that may lead to coal formation among the many tree trunks and the bark which were washed into the lake.

2. **Permineralization** -- Petrified wood is the most common type of fossil formed in this manner. The individual cellulose structure is replaced one molecule at a time until the material is rock rather then cellulose. Permineralization can also take place in bone or connective tissue. This was thought to take a great many years to accomplish. But in fact observation of wood and bone, when it is immersed in a brine solution for only a year, has shown that the mineral replacement can also be a relatively quick process.

3. **Cast** -- One of the more interesting fossils, and sometimes the only indication that a plant or animal was there, is the impression left after all else is gone. These are holes formed in the rock. They are most commonly reverse molds of snail shells or fern impressions. They can also be positive casts of the mold which give us a good impression of the organism's actual shape. Trilobites often fall into this group.

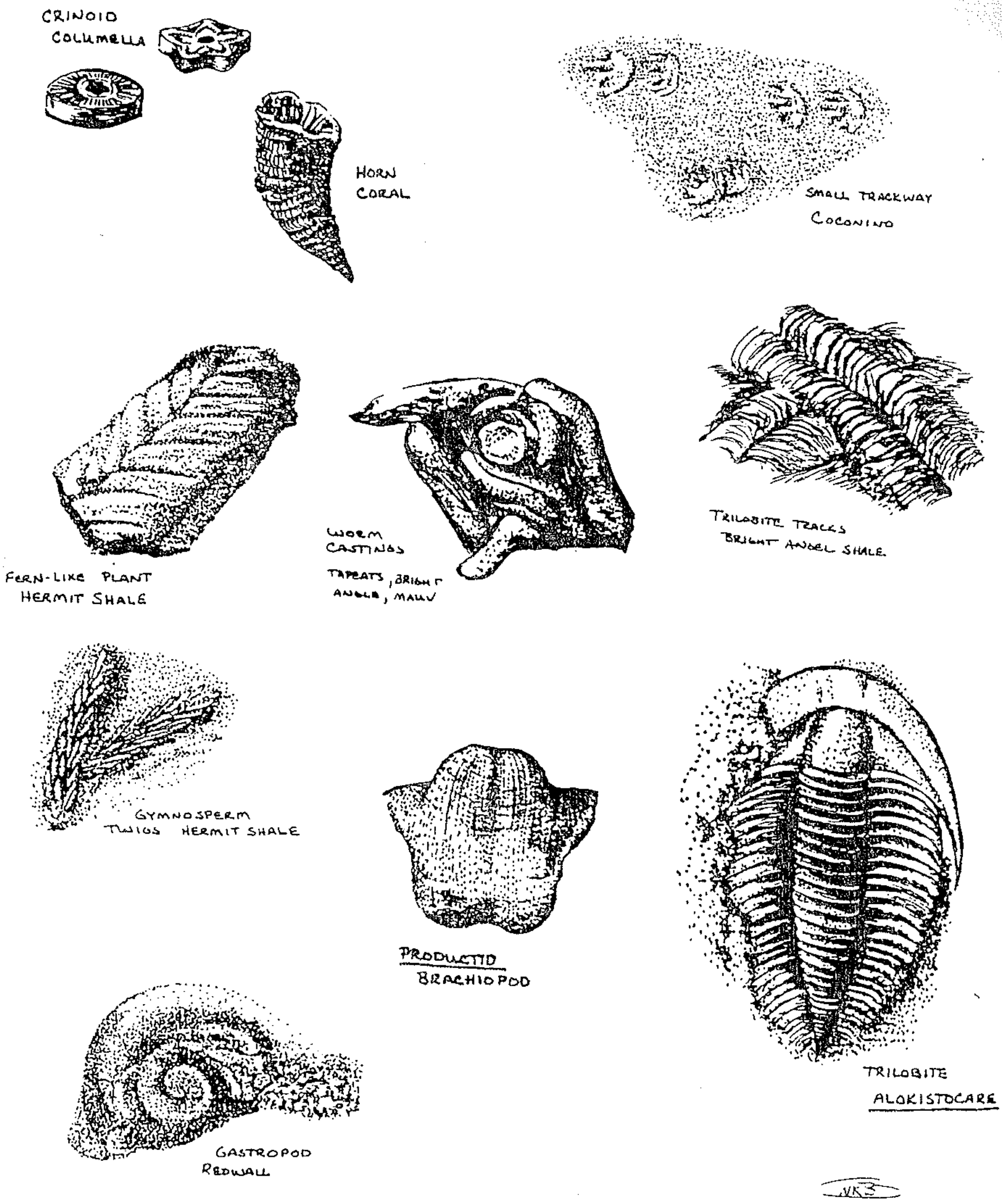
A specialized type of cast fossils which is of special interest is ichnofossils, or fossil trackways. These include the extremely common trilobite tracks of the Bright Angel, the worm tracks of the Tapeats and the vertebrate trackways of the Coconino and Supai formations. Ichnofossils are of particular interest because of their ephemeral nature and expected rarity. Trackways would seem to be rare because a shell can be washed from place to place and still be preserved, but a track made in soft mud must be buried and preserved where it was made. In fact, trackways of all types of vertebrates and non-vertebrates are common worldwide.

4. **Unaltered organic material** -- Because they are very hard and largely composed of inorganic salts, shells, corals, spines, teeth and bone plates may be preserved as the actual substance. These are most often found in fine grained limestone from which they may protrude by differential weathering, being slightly harder than the surrounding rock.

Fossils by formation

Within the Canyon, the fossils have been arranged in a general pattern which will help us recall and identify rocks as we see them. Starting from the top...

The Kaibab and Toroweap Limestones contain many mollusks, gastropods and brachiopods. The mollusks and gastropods most often appear as casts because their shells are somewhat more soluble in water than the brachiopods whose spiny shells are easily located along the walls of the trail or more commonly on fallen boulders which have weathered longer. Brachiopods are a bivalve, one valve (shell) bulges out and the other cups in. They may be seen as exposed valves or cross sections, often 2-4 inches across. Small crinoid columella are common in places. Where one is found, many are usually present. These are disks with a natural hole in the center. Some are round while others are pentagonal or star shaped. Many are very small, 1/8 to 1/4 inch in diameter. The crinoid has some similarities to the starfish and has a five sided symmetry.



COMMON FOSSILS OF THE GRAND CANYON

Another distinct fossil in the Kaibab, and any boulder containing it is certain to have come from the Kaibab, is the Kaibab sponge. A sponge is always seen in cross section embedded in the center of a chert nodule.

The Coconino Sandstone is famous for its vertebrate trackways. These can be seen in abundance along the Hermit trail, some along the Bright Angel and South Kaibab trails. I would suspect that some would be visible along any trail in the lower 1/3 of the formation. They are composed of tracks of many sizes from 1/2 inch to 4 inches across the foot in a trackway of two pairs of feet, sometimes with a tail dragging between, but often without. The Coconino is thought of by most geologist as fossil sand dunes. Originally they were attributed to wind blown sand, and because of this the Coconino has come to be considered the only non-water deposited layer in the Canyon. It was believed that the prints were made in dew or rain dampened sand. Dr. Leonard Brand of Loma Linda College has done considerable work on duplicating the trackways and his research has suggested that instead of being made in dampened dry sand, the best impressions are made when the sand is just saturated with water, suggesting that the sand dunes of the Coconino were formed not by wind current, but water currents under shallow water.

The brick red of the Hermit Shale is in stark contrast to the white sandstone of the Coconino. The Hermit Shale, being extremely fine grained silt stone has beautifully preserved fern and gymnosperm fossil impressions. These consist of small fern fronds and bristly sections of a pine-like scale plant. The Hermit Shale in many areas cleaves into thin lenses (layers), the fern impressions appearing on either side of the cleavage. Most often the fern or other plant material gives an impression of partial decomposition. Small (half to 3/4 inch) amphibian footprints can also be found in these cleavage planes forming short trackways of 3-8 impressions.

The Esplanade Sandstone in the Supai Group contains many larger animal prints, some of the most unusual looking much like horses hooves. McKee, former geologist for the Grand Canyon, notes at least two widely separated occurrences of the prints in the Canyon (McKee, E. D. 1982. Supai Groups of Grand Canyon, Geo. Surv. Professional Paper 1173), and describes them as quite an anomaly. The remaining Supai Formation contains brachiopods, mollusks, horned corals and other marine material, but very little is generally seen along the trail.

The massive, smooth Redwall Limestone is generally seen only in very limited areas, clambering over steep switchbacks and is missed, therefore, as fossil hunting grounds, but it is not without its exciting material. To the west of the Canyon in this formation fine ammonites are found, while in the Canyon we must be satisfied with corals, large and small crinoid columella, crinoid fans, brachiopods, bryozoans and other sundry sea creatures. Examine boulders in the Muav and Bright Angel which have fallen from the Redwall cliffs--otherwise a re-ascent away from the trail will be necessary to find fossil material.

The sometimes occurring Temple Butte is known for one fossil, the only placaderm plates found in the Canyon. A placaderm is a small fish with bony armor about his fore half. The Temple Butte is missing in most areas of the Canyon.

The Muav is somewhat more broken into blocks than the Redwall but it is nearly as inaccessible. Fossils here are much fewer. Worm burrows are the exception and worms seem to have thoroughly riddled the mud with their burrowing. Occasional broken pieces of brachiopods and trilobites are to be found.

The Bright Angel Shale is the green, often flaky strata just above the Tonto Platform. Here again worm borrows are exceedingly common. Along Bright Angel Creek the trilobite Alokistocare can be found in the formation, sometimes singly or in masses of collected cephalad plates. Along Hermit Creek trilobite trails are very common up to 3 inches across. Regrettably no trilobites of that size are to be found. An occasional hollowed out form in the trilobite tracks represents a trilobite "rosa" or resting place.

The Tapeats Sandstone is are the lowest of the Cambrian rocks, sitting in most areas on the igneous schist or granite of the inner gorge. Careful study will reveal few if any fossils except ~~ichnofossils~~ trace fossils which abound. Annelid worm tracks of several varieties can be found. Some are short surface trails with a small ridge on each side, while others are "U" shaped burrows. A series of quadrupedal vertebrate tracks have also been found in the Tapeats.

schists metamorphic

In the Grand Canyon Series of Precambrian rock some alleged fossil material has been found. The most famous are jellyfish like medusas. There is much doubt as to their validity. The only universally recognized fossils in the Precambrian strata are algae. Here in the Grand Canyon, as elsewhere throughout the world, the amazing fact is the sudden "explosion" of fossils at the Precambrian/Cambrian boundary. Nowhere in the world has any Precambrian rock yielded a plausible ancestor for any of the simple or complex creatures found in the Cambrian. The total absence of any transitional forms between microscopic, single-celled, soft-bodied creatures, such as bacteria and algae (many fossils of which have been found) and the complex multicellular creatures whose fossils are found in exceeding abundance in Cambrian rocks, is powerful positive evidence for creation.

Fossils and their story

Fossils in the Grand Canyon help us to create theories as to how they got there. The evolutionary geologist with his uniformitarian concept of geology suggets that the area of the Grand Canyon was alternately a fresh water lake, lowlands with meandering streams, shallow marine zone, and brackish water deposits. Except for the Coconino all of the layers are accepted to have been laid down by water.

The Coconino's story has been slow to be ferreted out. Some of the very first writing about it (Schuchert, C. 1918. On the Carboniferous of the Grand Canyon of Arizona. Am. J. of Sci., vol. 45, p. 351) suggested it was laid down by winds in shallow fresh water but later writing attributed it fully to eolian, wind blown sources. More recent work (Brand, L. 1979. Field and Laboratory studies on the Coconino Sandstone [Permian] Vertebrate Footprints and their Paleoecological Implications. Palaeography, Palaeoclimatology, Palaeoecology, vol. 28, pp. 25-38) has indicated the more probable origin of the footprints in well watered sand and Dr. Austin has suggested an underwater deposition. This suggests that the Coconino, like other strata, is water deposited.

The evolutionist has long looked at the Grand Canyon with its deep exposure as representing a series of open pages to the progressive development of life. At the bottom in the "primitive" algae, replaced by the worm and trilobites, only to be replaced in turn by the brachiopods and mollusks, with amphibians showing the way to the future lords of the earth. Yet, if as evolutionists claim, the Canyon is a record of evolution, then a multitude of transitional forms should be found in every one of it's formations. As a matter of fact, no transitional forms have been found in any of these open pages.

One of the most striking exceptions to this scenario is the appearance of apparent quadrupedal vertebrate tracks in the Tapeats Sandstone. By evolutionary standards this would place highly specialized animals, perhaps even mammals, walking on legs which are relatively long and rotated under the body in a narrow, long stride. The appearance of such an animal in the size range of a lion or tiger would be a striking exception to the worms and trilobites which the evolutionary paleontologist attributes to be the most likely form of animal life walking around 450 My ago. The fossil evidence for this striking exception consists of 20+ footprints complete with mud pushups scattered over a 100 sq. meter area. The original site was recognized by John MacKay of Australia in October of 1984 on a trip through the Canyon with Dr. Gary Parker, then of ICR. Originally, four prints were recognized, but further mapping with some research has been done. This work has resulted in the locating of 26 possible prints falling into 3 size ranges and possibly representing several trackways. We are looking forward to a full research project in the next two to three years to verify this scenario.

What is the alternative to the non-evolutionist view to explain what we can see about us everywhere? We believe the Flood model is the most viable alternative. In building a Flood model of how the waters acted on the face of the earth, the Grand Canyon proves a stimulating textbook. The Scriptures provide the framework for understanding the behavior of the waters on the earth during that year of the Flood. If we start with the concept that all of the level Grand Canyon strata were laid down by the Flood's waters during that year, we run into an interesting suggestion as to the effect of water on life. From the earliest days of the Flood to the end, sea life paid the highest toll. Vertebrates were apparently able to escape, at least for a time, in this location. We find trackways in the Tapeats, again in the Supai, the Hermit Shale, the Coconino, and other strata above the Kaibab outside of the park.

A model of the Flood which calls for deep tranquil waters of long duration would provide no opportunity for vertebrates to touch ground under the water to leave tracks. A model calling for deep, turbulent waters would not only deny access to the land surface, but would obliterate trackways in their continual reworking of the sediments. By contrast, a wave model which does not require deep waters, allows for heavily sediment laden waves which move across broad surfaces of relatively flat land and in the process are forced to drop part of their sediment load in proportion to their decreased speed and lost carrying capacity. This would suggest a major scattering of marine fossils being carried with the sediments and buried but for a time, at least highly mobile quadrupeds would find some escape possible, trackways being mute evidence of attempted routes of escape. But even this attempted escape was only for a time.

Above all, the fossils of the Grand Canyon are mute evidence that nothing escaped the judgment of God. The world that then was is buried nearly one mile deep in sediment. God, for the sinfulness of mankind, destroyed His entire earth by water. In a true sense, the Grand Canyon is a giant graveyard testifying to God's judgment of sin, but His mercy toward us, His creation.

ADAPTATIONS: HOSPITALITY IN A HARSH ENVIRONMENT

by John R. Meyer

Participants of the ICR Grand Canyon Adventure will have ample opportunity to observe characteristics of one of the great deserts of the world. The North American desert is the fifth largest, encompassing approximately one-half million square miles of dry, hot, and often desolate country. The North American desert is often subdivided into the four areas shown in Figure 4.1. The Great Basin, lying in the rain shadow of the high Sierras on the West and the Rockies on the East covers all of Nevada and parts of adjacent states to the east and north. The Mohave desert lies between Los Angeles and Las Vegas. The Sonoran desert in the United States covers southeastern California, southern Arizona, and much of northwestern Mexico. The Chihuahuan desert extends from south central New Mexico to the heart of old Mexico.

Participants joining the trip in San Diego will enter the Sonoran desert east of El Cajon. Those joining us in Phoenix will immediately find themselves in a desert metropolis. The Sonoran desert will fade out an hour or so north of Phoenix as higher country is encountered. Once we reach the Grand Canyon, however, our desert experience is not over. River rafters and canyon hikers alike will see as much (in some cases more) than they like in the lower reaches of the canyon itself. Hikers, in particular will need to take seriously the warnings about lack of water in the canyon. Make no mistake, this is desert country. Those touring on the bus will encounter the southern reaches of the Great Basin desert as they travel north or east of the Grand Canyon area.

While human beings may be scarce in most parts of the desert (large cities like Phoenix, Tucson, Las Vegas and Salt Lake City are obvious exceptions), plants and animals are not. It is tempting to think of many parts of the desert as largely devoid of life. Nothing could be farther from the truth. Anyone who has ever witnessed a desert "bloom" which results from a favorable conjunction of season, moisture, and temperature will testify to the riotous profusion of flowers, of colors and blossoms which can coat the desert floor. Even the animals, which at first glance seem absent, are present in large numbers. The careful observer will note delicate telltale signs in the sand which temporarily record the movements of small mammals, insects or even an occasional reptile.

How is it possible that living systems, all of which depend on water-based chemical reactions at moderate temperatures, can exist and even flourish in the desert where lack of water and lethal temperatures are characteristic? What features do desert organisms have that allow them to live hospitably in a harsh environment?

DESERT PLANTS

Most plants are composed of at least 80% water. Thus, desert plants can only survive if they can obtain and preserve significant quantities of this vital substance. Some desert plants avoid the problem altogether by growing only in riparian (stream bank) environments or close to other areas where long tap roots can usually reach the water table. Trees such as the tamarisk,

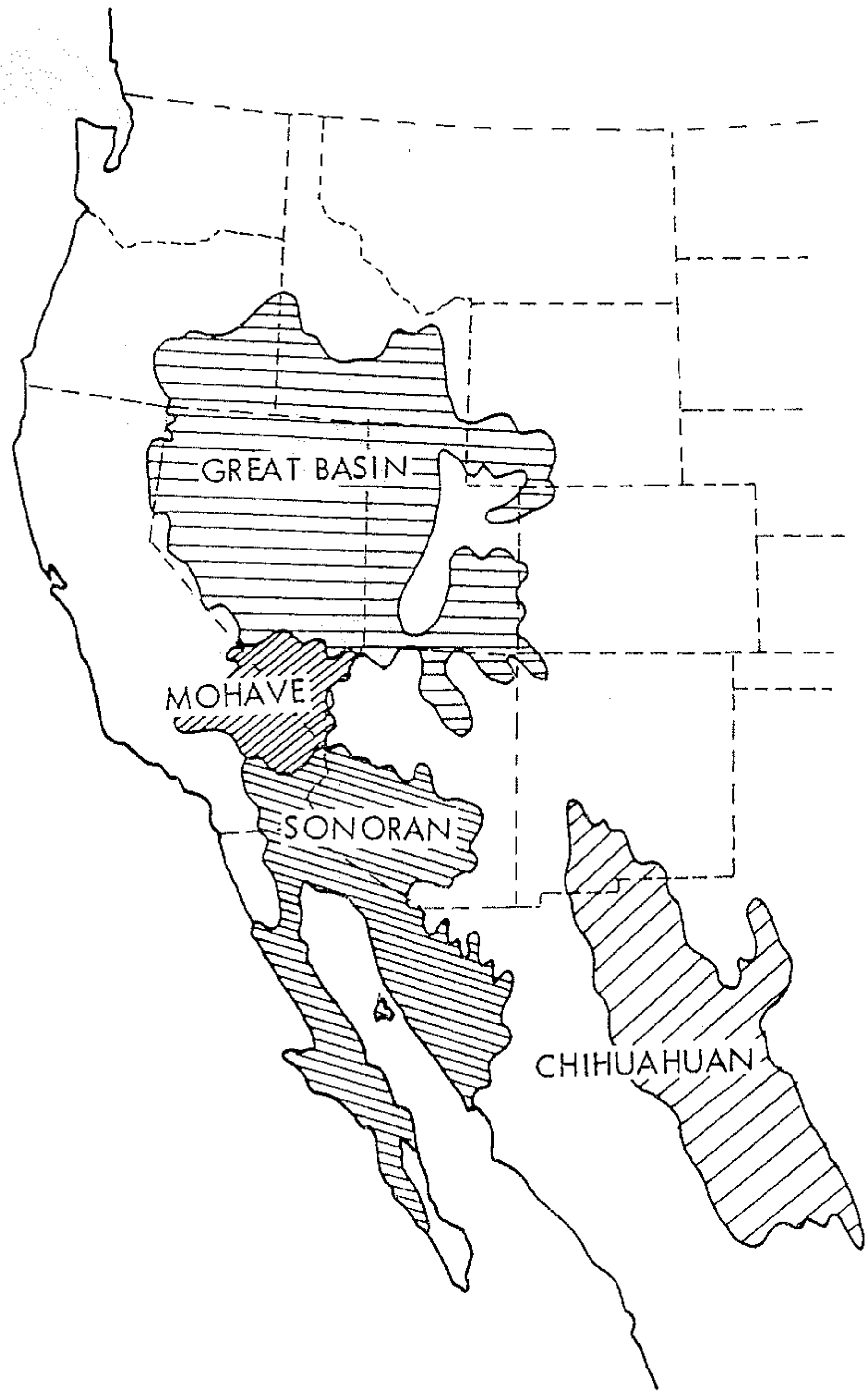


Figure 4.1 Four subdivisions of the North American desert.

cottonwood and sycamore are representatives of this type and may often be seen growing along the Colorado River, both in southern Arizona and in the Grand Canyon itself. A number of intermittent streams north of Phoenix support an adequate water table and green trails across the arid desert here often reveal the otherwise hidden presence of ground water.

There is another way of avoiding arid conditions. Many seeds exist in what might be called suspended animation. During this time, before germination, the living germ cells inside the seed can exist without external water. When adequate soil moisture is present, these seeds rapidly germinate and in a matter of a few days put forth stems, leaves and flowers. Pollination occurs, and new seeds are produced before soil moisture plummets to lethal levels. As drought conditions ensue, the parent plant dies but the seeds, now fully mature, survive until germination is triggered by another rain shower. These plants, called ephemerals, appear only occasionally on what otherwise may appear to be a totally barren desert area.

The presence of moisture is not the only signal for germination for some plants which grow along dry washes. These intermittent streams may be totally dry for all but a few days a year. However, during sudden rainstorms they are often the scenes of violent but short-lived flooding. Seeds shed along and in such streams are subject to considerable abrasion by rocks and gravel during the flood. The tough seed coat is scarred or broken, providing the stimulus for rapid germination in the now moist stream bed. Germination in seeds of the ironwood, palo verde and smoke trees is controlled in this fashion.

Many plants of the desert are extremely drought tolerant. They may be able to resist severe desiccation by a number of means. Some have reduced leaf surface area through which evaporation might occur. In these the green chlorophyll needed for photosynthesis is found extensively in the stems. Others may be able to curl the leaf into a roll to avoid direct sunlight exposure. Some may turn the leaf sideways so that only the edge is directly facing the hot sun. The leaves of many desert plants have a thick waxy covering which slows evaporation.

While water is scarce in the desert at most times, there are occasional rains. Some desert plants take advantage of this by quickly absorbing and storing large quantities of water. Perhaps the best example of this is the stately saguaro cactus which may be seen spreading its giant arms throughout southern and central Arizona. A mature specimen may exceed 50 feet in height and weigh over ten tons. Over 80% of this weight may be water. The saguaro is equipped internally with fleshy cells which may rapidly take up water. The trunk of the cactus has vertical, accordian-like pleats which allow the trunk to expand as water is drawn in through an extensive root system. This stored water is sufficient to keep the saguaro alive through many months of drought.

Some plants meet arid conditions by giving up. Selective die-back of older branches and leaves slow evaporation, reduce the need for water in photosynthesis, and preserve precious water resources. The wide-spread creosote bush is perhaps the most hardy of all desert bushes, surviving in areas where temperatures often exceed 120 F° and rainless periods are often more than a year in length. It uses a combination of features including selective die-back, drought tolerance, and an extensive root system to allow it to be almost the sole inhabitant of very harsh desert areas.

DESERT ANIMALS

The biologist studying plants has a significant advantage over the biologist who studies animals. The botonist simply walks up to the plant and begins the study. The zoologist first has to catch his little critters. But it is precisely this ability to hide and be secretive which allows many small mammals to survive in the desert. It is also this habit of secretiveness which gives the desert its deceptive appearance of lack of animals. Driving the back roads of the desert at night will often reveal just how heavily populated the country really is.

The surface of the desert and the air next to it may become incredibly hot in direct sunlight. Desert nights, because of low humidity and lack of cloud cover may become unbelievably cool--even in places like Death Valley. However, the temperature a few feet below the surface in the den of a desert rodent may remain a comfortable temperature throughout the 24-hour cycle. It should not be surprising then to find such small mammals tucked away in the cool subsoil below the blistering hot surface. Most small desert mammals are nocturnal; that is, they are active primarily at night. Even their mid-day forays are marked by rapid returns to their relatively cool den before body temperatures can rise to uncomfortable levels. This kind of temperature control is called behavioral thermoregulation. Other types of behavioral thermoregulation which may be practiced by a wide variety of desert animals include shade resting, orientation parallel to the sun's rays to reduce heat exposure and migrating out of arid regions during drought season.

Many animals, like some plants, although living in the desert, do not face a lack of water because they live in or around riparian environments, oases, or man-made lakes. Others may subsist almost exclusive on succulent plants or insects. An example of a complex ecological association is presented by a large number of fruit fly species. The fruit fly, long a favorite subject of study of the laboratory geneticist, is found throughout the warmer parts of the world. A fairly large number of species are confined to the North American Desert. Here, unique species of fruit flies eat select species of yeast which are found in the rotting parts of particular cactus species. The fruit flies themselves would rapidly desiccate in the dry, hot desert air, but find shade, water, and food in the rotting parts of the cacti.

One way to exist in a dry environment is to carefully conserve water resources. The kangaroo rat, for example, probably never takes a drink in its entire life time. Carbon dioxide, water and energy release are the results of the combustion of fuel. As oxygen combines with carbohydrates, carbon dioxide is formed from the burning of the carbon molecule and water is formed from the hydrogen molecule. In like manner, the metabolism which powers living animals, produces carbon dioxide, water and energy release. This metabolic water, if conserved, is sufficient to meet the needs of many small rodents. These rodents retreat to burrows during high temperature thus keeping evaporation to a minimum. They have very efficient kidneys which produce a urine relatively low in water concentration, and they produce very dry feces. Their ability to exist on metabolic water (probably along with licking up some dew) means they have no need for drinking water.

Some foods are especially good at allowing the formation of metabolic water. Seeds are particularly good in this respect; and, strange as it may seem they are abundant in the desert. Parts of the North American desert have been found to contain from 5,000,000 upwards to 100,000,000 seeds per acre. One kangaroo rat was found to have over 900 seeds tucked away in his cheek pouches. Caching of seeds appears to be a compulsive habit of many arid country rodents. In deserts characterized by continually shifting sand and dunes, some insect species live their entire lives under the sand, existing entirely on organic matter, including seeds which have blown in and been covered.

Bigger mammals such as big horn sheep and the burros which may be encountered within the Grand Canyon itself are sufficiently mobile to gain access to water, at least every few days, but they do have a problem with the heat. While we normally think of hair in animals as a means of protection from the cold, it also provides protection from direct radiation from the sun. The fur or hair of an animal acts as an insulator, slowing heat flow in either direction. These animals, along with camels in the Old World deserts, have the ability to withstand a considerable rise in temperature. This stored heat is then given up at night as the animal cools down.

Perhaps one of the most interesting features of temperature control is found in the jackrabbit. These large floppy-eared rabbits inhabit not only the deserts of the southwest, but also large reaches of midwestern prairie. At one time it was supposed that the large ears were used to enhance their hearing ability. However, it has been found that their ears perform a far more important function. Laboratory investigations on heat-stressed jackrabbits have indicated that the blood leaving the ear is significantly cooler than the blood entering the ear. During heat stress it can increase ear blood flow to very high levels through expanded blood vessels. The research indicates that the large, nearly bare ears serve as very efficient heat radiators! Thus, a jackrabbit, even in the mid-day heat, may sit in the shade of a bush with its ears errect, and radiate sufficient heat toward the cool portion of the sky (away from the sun) to prevent it from reaching uncomfortable temperatures. Studies on a number of large mammals which possess permanent horns with high blood circulation have shown that these structures also are useful in heat regulation.

DESIGN FOR DESERT LIVING - A CREATIONIST INTERPRETATION

Larson has suggested:

> Some animals have adapted morphologically or physiologically, or both, to desert conditions. Primarily, however, body adaptations consist not of new mechanisms but rather of the evolutionary enhancement and increased development and use of characteristics common to the animal's basic group--that is, quantitative rather than qualitative changes. To a greater degree, however, most desert animals have adapted to their environment behaviorally.

As a creationist I would agree with parts of the above statement. A creationist interpretation of adaptation to desert conditions would certainly include quantitative alterations, behavioral adaptations, and morphological and physiological adaptations but would stress that these variations were well within the "Genesis kind" limitations. In view of this, one possible creationist interpretation would be that organisms were created with broad genetic capacities, many of which lay concealed or dormant until after the flood of Noah. With the opening up of entirely new ecological niches, such as desert environments, these already potentially existing adaptations could be uncovered and their presence revealed by many of the desert adaptations which we now take for granted. The Creator has thus provided for desert organisms a high degree of hospitality in a harsh environment.

BIBLIOGRAPHY

The following references are suggested for further study of desert organisms:

Larson, Peggy, 1977, The deserts of the southwest: a Sierra Club naturalist's Guide: Sierra Club Books, San Francisco.

Leopold, A. Starker and the editors of Life, 1961, The Desert: New York, Time Inc.

Hoffmeister, Donald F., 1986, Mammals of Arizona: University of Arizona Press and the Arizona Game and Fish Department.

RAFT TRIP ITINERARY

The following is a summary of the events of each day and the locations of camp each night on the raft trip. Our schedule may vary from that given depending on the conditions of the beach at each camp site. The book, The Colorado River in Grand Canyon, by Larry Stevens, will be provided to each raft trip participant and provides a general map of the route as well as discussion of some main points of interest. Use the book to supplement this itinerary, but remember that it is written from an evolutionary and uniformitarian framework.

We look forward to a safe, informative, active and spiritually uplifting adventure as we float 87.5 miles in the eastern Grand Canyon!

Our Faculty:

Steven A. Austin, Ph.D.
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Santee, CA 92071

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Dean, ICR Graduate School
Institute for Creation Research
Santee, CA 92071

Our Purpose:

As we float almost ninety miles through the Grand Canyon, we seek to understand God's creation better through observation and inquiry, particularly in the areas of geology, biology, and anthropology in the light of His Word. In particular, we seek to inquire into the record left by Noah's Flood and how such an interpretation is in accord with the scientific evidence. Basic to all activity is, however, our desire to reinforce the absolute reliability of the Word of God in the mind of each participant, that his or her testimony of the Lord Jesus Christ might be wonderfully enriched.

Our Raft Operator:

Western River Expeditions
7258 Racquet Club Drive
Salt Lake City, UT 84121

Sunday, April 10

Bus departs Grand Canyon Village for Lee's Ferry at 12:00 noon. Launch rafts from Lee's Ferry at 3:00 p.m. and float 8 miles to Badger Creek Rapids. Camp in Badger Canyon (mile 7.8 on Colorado River).

Monday, April 11

Launch raft from Badger Creek Rapids and float 33 miles to Buck Farm Canyon. Camp at Buck Farm Canyon (mile 41.0 on Colorado River). Observe or stop at Soap Creek, South Canyon, Vasey's Paradise, Redwall Cavern, and Nautiloid Canyon (mile 34.5). Study strata and fossils. Observe animals and plants.

Tuesday, April 12

Launch raft from Buck Farm Canyon (mile 41.0 on the river) and float 23.5

miles to Carbon Creek (mile 64.5 on river). Camp at Carbon Creek. Observe or stop at Saddle Canyon, Nankoweap Canyon and Indian ruins, and the Little Colorado River. Study the "Great Unconformity." Explore Indian granaries at Nankoweap.

Wednesday, April 13

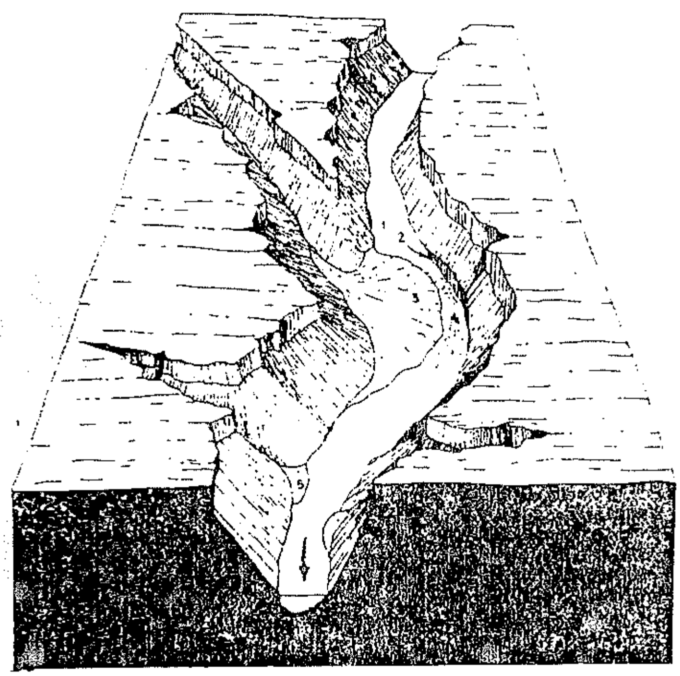
The rafts stay at Carbon Creek. Day hike made up Carbon Creek to study Cambrian and Precambrian rocks, the "Great Unconformity," the East Kaibab Monocline and the Butte Fault. Camp at Carbon Creek.

Thursday, April 14

Launch rafts from Carbon Creek (mile 64.5 on river) and float 21.2 miles to Cremation Creek (mile 85.7 on river). Observe or stop at Lava Canyon, Tanner Canyon, Cardenas Creek, Unkar Creek, and Hance Rapids. Camp at Cremation Creek. Observe Precambrian strata, river ecologic communities, and Indian ruins.

Friday, April 15

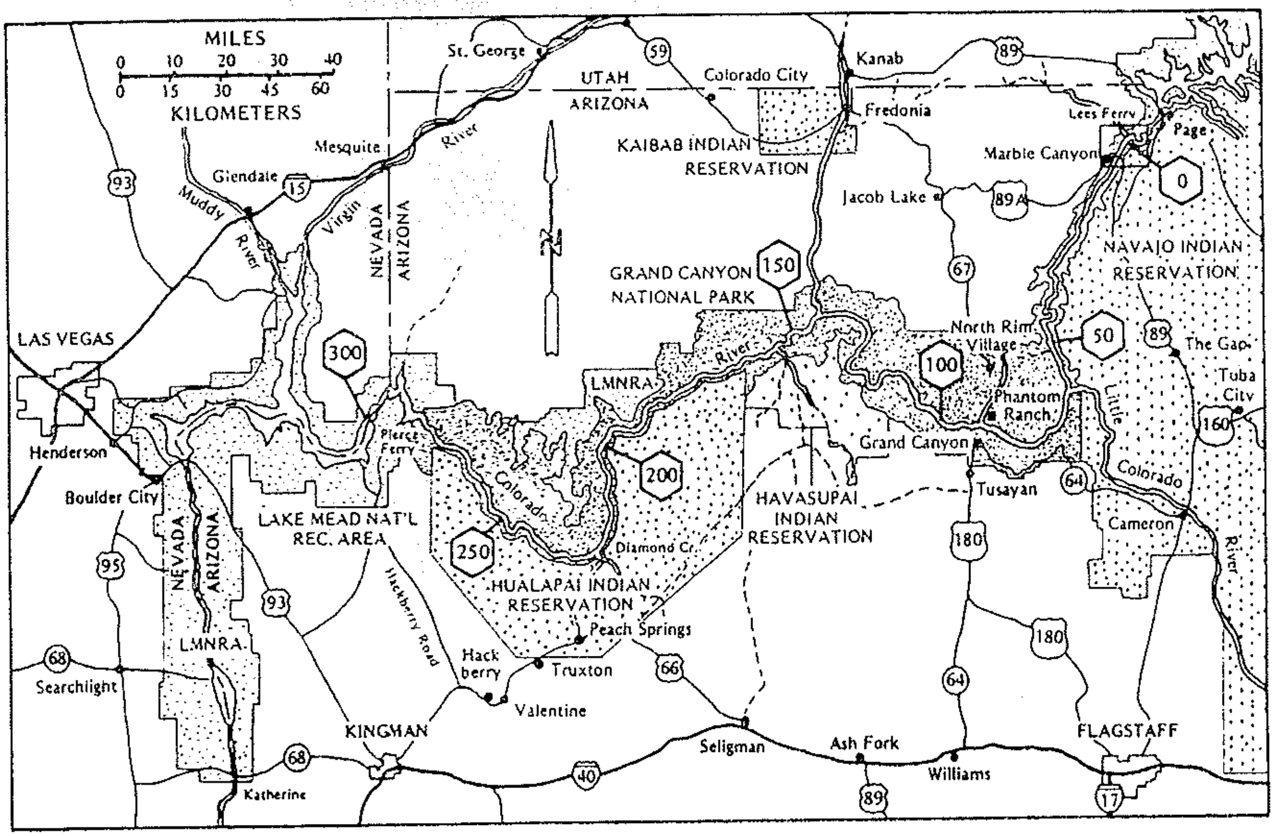
Launch rafts from Cremation Creek (mile 85.7 on river) and float two miles to Bright Angel Creek next to Phantom Ranch (mile 87.5 on the river). See Kaibab Suspension Bridge. Hike up Bright Angel Trail 9.5 miles from river to south rim. Arrive south rim Grand Canyon Village by 5:00 p.m. A bus will pick us up and transport us to our motel.



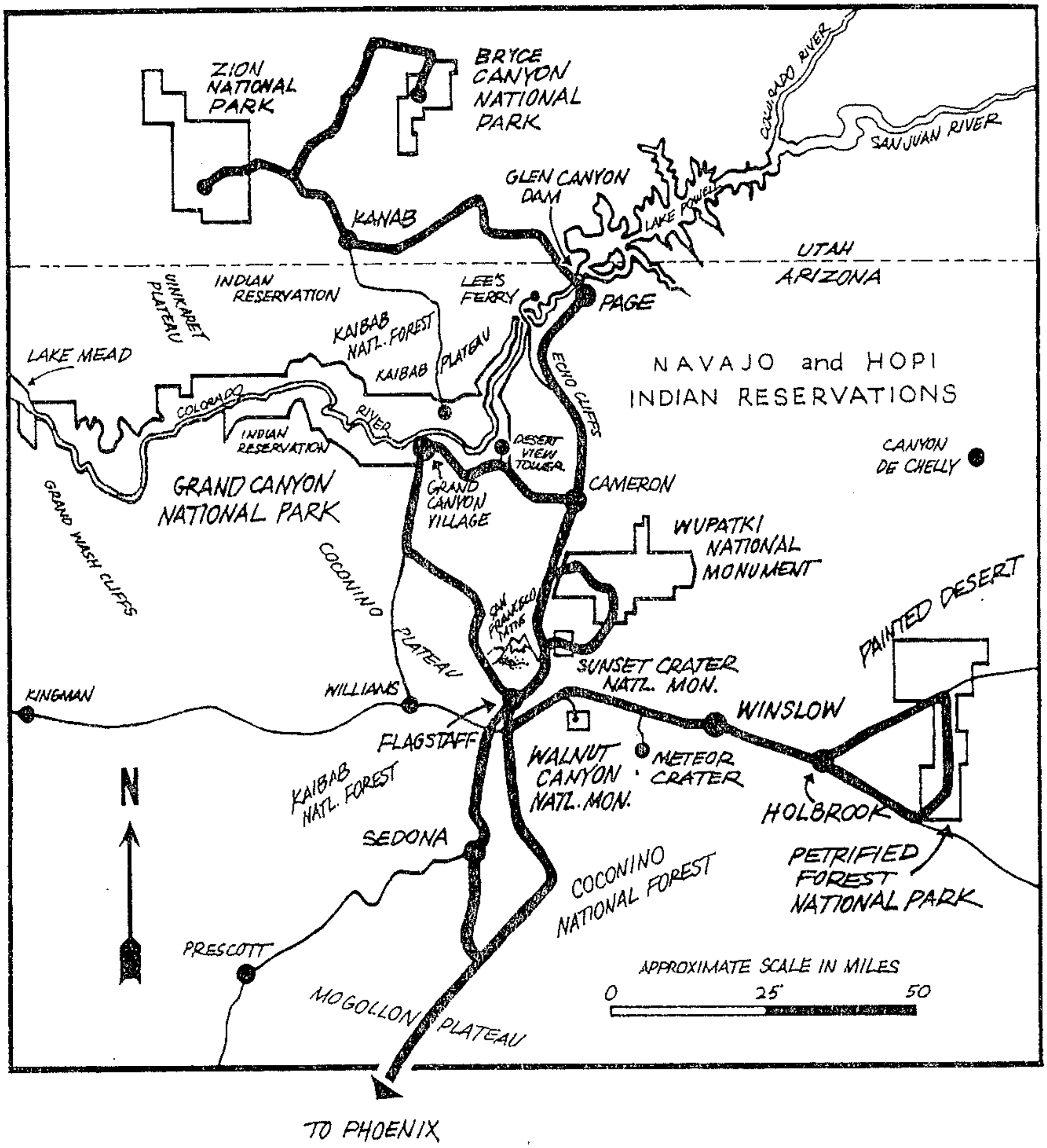
BLOCK DIAGRAM ILLUSTRATING THE CAUSE OF RAPIDS IN THE COLORADO RIVER

1. Quiet water
2. River-cut rock face
3. & 5. Fan-shaped debris deposit
4. Rapids

(From W.K. Hamblin and J.K. Rigby, Guidebook to the Colorado River)



MAP OF THE GRAND CANYON REGION


ZION NATIONAL PARK
BRYCE CANYON NATIONAL PARK
COLORADO RIVER
SAN JUAN RIVER
GLEN CANYON DAM
LAKE POWELL
KANAB
UTAH
ARIZONA
UINKARET PLATEAU
INDIAN RESERVATION
LEE'S FERRY
PAGE
KAIBAB NATL. FOREST
KAIBAB PLATEAU
LAKE MEAD
NAVAJO and HOPI INDIAN RESERVATIONS
ECHO CLIFFS
COLORADO RIVER
INDIAN RESERVATION
DESERT VIEW TOWER
CANYON DE CHELLY
GRAND CANYON NATIONAL PARK
GRAND CANYON VILLAGE
CAMERON
GRAND WASH CLIFFS
COCONINO PLATEAU
WUPATKI NATIONAL MONUMENT
SAN FRANCISCO PEAKS
PAINTED DESERT
SUNSET CRATER NATL. MON.
KINGMAN
WILLIAMS
WINSLOW
FLAGSTAFF
WALNUT CANYON NATL. MON.
METEOR CRATER
N
KAIBAB NATL. FOREST
HOLBROOK
SEDONA
PETRIFIED FOREST NATIONAL PARK
COCONINO NATIONAL FOREST
PRESCOTT
APPROXIMATE SCALE IN MILES
0
25
50
MOGOLLON PLATEAU
TO PHOENIX

ITINERARY FOR
NORTHERN ARIZONA/SOUTHERN UTAH BUS TOUR

Monday, April 11 - Friday, April 15, 1988

by Tom Manning

BUS TOUR IN OVERVIEW

Faculty: Dr. Henry Morris, Dr. Duane Gish, Dr. John Meyer, Ken Ham, Sam Franks, Bill Hoesch, and Mrs. Hannah Rush

Coordinator: Tom Manning

Purpose of Trip:

By visiting some of the more popular natural areas of the U.S., we seek to understand God's creation better through observation and inquiry, particularly in the areas of geology, biology, and anthropology in the light of His Word. In particular, we seek to inquire into the record left by Noah's Flood and how such an intepretation is in accord with the scientific evidence. Basic to all activity is, however, our desire to reinforce the absolute reliability of the Word of God in the mind of each participant, that his or her testimony of the Lord Jesus Christ might be wonderfully enriched.

ITINERARY OF BUS TOUR

Monday, April 11

11:00 a.m.	Load suitcases and personal items onto bus parked by sidewalk in front of your room
11:55	Board Bus in front of Maswik Cafeteria
12:00 noon	Bus tour departs from Maswik Cafeteria
12:30 p.m.	Stop at Desert View for enjoyment of eastern Grand Canyon and discussion of geology
1:15 p.m.	Depart from Desert View for Wupatki Indian Ruins Nat'l Monument
2:45 p.m.	Arrive at Wupatki Indian Ruins. Lecture
3:30 p.m.	Depart Wupatki for Sunset Crater
4:30 p.m.	Arrive Sunset Crater Nat'l Monument. Tour Visitor Center and Lava Trail
5:30 p.m.	Depart Sunset Crater for Flagstaff
6:00 p.m.	Arrive Flagstaff, Quality Inn (602)774-8771

Tuesday, April 12

7:30 a.m.	Place suitcase in hall, load personal items onto bus
7:55 a.m.	Board bus
8:00 a.m.	Depart Flagstaff for Meteor Crater
9:00 a.m.	Enjoy the museum and view at Meteor Crater
10:30 a.m.	Depart Meteor Crater for Petrified Forest
12:00 noon	Arrive at Petrified Forest Visitor's Center and cafeteria for lunch
1:30 p.m.	Depart Petrified Forest Visitor's Center
1:45 p.m.	Arrive at Puerco Indian Ruins for a short 20 minute lecture

2:10 p.m.	Depart Puerco Indian Ruins for Agate House and Long Logs
2:30 p.m.	Arrive at Agate House and Long Logs Visitor area
3:30 p.m.	Depart Petrified Forest Nat'l Park for Wood Prospecting area/rock shop
4:00 p.m.	Arrival at Rock Shop to prospect for petrified wood on lands outside of the National Park
5:30 p.m.	Depart Rock Shop for Holbrook, Best Western Arizonian Inn (602)524-2611

Wednesday, April 13

7:30 a.m.	Place suitcase in hall, load personal items onto bus
7:55 a.m.	Board bus
8:00 a.m.	Depart Holbrook for Walnut Canyon National Monument
10:00 a.m.	Arrive at Walnut Canyon
11:30 p.m.	Depart for Flagstaff
12:00 Noon	Arrive Flagstaff - Lunch
1:00 p.m.	Depart for Cameron Indian Trading Post
2:30	Arrive Cameron
3:30	Depart for Page, Arizona
5:30 p.m.	Arrive Page, AZ (602)645-2466
	NOTE: (1) We will spend two nights at this motel (2) EARLY (7 A.M.) DEPARTURE TIME TOMORROW

Thursday, April 14

6:55 a.m.	BOARD BUS
7:00 a.m.	Depart Page for Zion National Park
10:00 a.m.	Arrive Zion, Tour Visitor Center
11:00 a.m.	Depart Zion for Bryce Canyon Nat'l Park - (Box lunches on bus)
2:00 p.m.	Arrive Bryce Canyon Visitor Center
4:00 p.m.	Depart Bryce for Page after having visited view sites in park
7:00 p.m.	Arrive Ramada Inn, Page, AZ. (602) 645-2466

Friday, April 15

7:45 a.m.	Place suitcase in hall, load personal items onto bus
7:55 a.m.	Board Bus
8:00 a.m.	NOTE: DEPART RAMADA INN FOR BREAKFAST AT WAWEAP LODGE, LAKE POWELL MARINA
8:30 a.m.	Arrive Waweap Lodge for breakfast
10:00 a.m.	Depart Waweap Lodge for Glenn Canyon Dam
10:30 a.m.	Arrive Glen Canyon Dam for tour of dam
11:30 a.m.	Depart Glen Canyon Dam for Lee's Ferry - (Box lunches on bus)
1:30 p.m.	Arrive Lee's Ferry
2:30 p.m.	Depart Lee's Ferry for Navajo Bridge/Marble Canyon
3:00 p.m.	Arrive Navajo Bridge/Marble Canyon Observation Site
3:30 p.m.	Depart Navajo Bridge for South Rim Grand Canyon, Yavapai Lodge
5:30 p.m.	Arrive Yavapai Lodge-East, phone (602) 638-2525

DESCRIPTIONS OF MAIN POINTS OF INTEREST FOR THE BUS TOUR

by Hannah Rush and Bill Hoesch

TUSAYAN PUEBLO, GRAND CANYON NATIONAL PARK
1185-1210 A.D. - Culture: Anasazi

Grand Canyon National Park contains approximately 300 prehistoric Indian ruins. Most of them are hidden in remote parts of the canyon and are so inaccessible they are seldom seen by visitors. The majority of the sites are relatively small, but have yielded valuable artifactual material. The rafting group will pass by one of these sites called Nankoweap, a cliff-dwelling in the canyon bottom. The bus tour will stop at Tusayan Pueblo, on the south rim of the canyon.

Tusayan is an Anasazi settlement built about 1185 A.D. It was inhabited by about 20 people for approximately 25 years. The estimated time of habitation was determined by the amount of refuse left at the site, patterns of wear on manos and metates, and the different styles of pottry made during this time. The pueblo has about 15 rooms, with about half used for living, the rest for storage. Ladders were positioned through the smoke holes atop the flat roofs and served as doorways. Most daily activity was conducted outdoors, where the Anasazi farmed, collected wild plants, hunted, and made pottery and other essentials. To supplement the meager natural rainfall, they built check dams to trap runoff water, which made agriculture possible. These dams can still be seen to the northeast of the pueblo.

DESERT VIEW TOWER, GRAND CANYON NATIONAL PARK

Desert View is the most eastern vantage point to view the Grand Canyon, and provides a good introduction for our trip. It is especially a good place to talk about geology.

Beginning at the bottom of the Grand Canyon is one of the world's finest examples of an angular unconformity, "The Great Unconformity," where the lowermost Pre-cambrian strata are uptilted and overlain by the relatively horizontal sequence of Tapeats Sandstone, Bright Angel Shale, etc. The rock layers can be traced right on up to the Kaibab Limestone upon which we stand. Since all of the bedded rock before us must have originally been deposited as sediment horizontally (or nearly so), then we must infer that later earth movements have taken place where these strata are uptilted or bent. Two excellent examples of such movement can be seen from this overlook that have occurred as two distinct events in earth history: the East Kaibab Monocline and the uptilted beds beneath the Great Unconformity. Might the Great Unconformity mark the onset of Noah's Flood?

As we look to the east, a step-like terrain, called "The Grand Staircase," rises to the top of Black Mesa. These exposures are remnants of strata that lie above the Kaibab Limestone and probably covered the area of the present Grand Canyon prior to uplift and erosion. We will be driving in this area in the next few days. Rock layers such as the Chinle Formation, which contains the great logs of the "Petrified Forest" and the Morrison Formation, with its world-famous dinosaur skeletons, are preserved there. In fact, if a well were drilled from the top of Black Mesa, a "layercake" of some 8,000 feet in thickness would be penetrated, including a strata sequence very similar to those exposed in the Grand Canyon, before the Great Unconformity would be penetrated. So then, which of the rock strata before us may be interpreted as the closing stages of the Great Flood? We look to the upper layers, such as those exposed on Black Mesa, for evidence.

WUPATKI NATIONAL MONUMENT, ARIZONA
1100-1225 A.D. - Culture: Anasazi

"Come, behold the works of the Lord, what desolations he hath made in the earth" (Psalm 46:8).

As we enter this very desolate region of Northern Arizona, we ask ourselves just how people could have survived and even thrived in this land. Yet they did. For just over a hundred years the Wupatki area was a cultural melting pot, with a population of around 4000.

Before the eruption of Sunset Crater 18 miles south, in 1064-1065, the population was scattered and small. The people lived, then, in pit houses, where they hunted, gathered, and did some farming. They are known as the "Sinagua" people, from the Spanish for "without water." They probably had some warning of the eruption because of earthquakes and the opening of fissures in the vicinity. They apparently gathered their belongings and fled. The eruption covered 800 square miles with ash, which provided a rich mulch and reduced evaporation from the soil. The Indians moved back into the area to farm and build what are now the pueblos.

Wupatki Pueblo, called "Tall House" because of its three story units, contains some 100 rooms, a large kiva, and a ball court. The uncovering of the ball court in 1965 gave clear evidence of influence from the Hohokam to the south. Also, such trade items as copper bells, shells, parrots and macaws indicate contact with the Hohokam and possible Chaco Canyon in New Mexico.

Examples of fine architecture and decorative walls can be seen at Wupatki. The area was abandoned by 1250 A.D., shortly before the Great Drought of 1276-1297.

SUNSET CRATER NATIONAL MONUMENT, ARIZONA

Sunset Crater and the entire region known as the San Francisco Peaks Volcanic Field of which it is a part, is a good example of vast amounts of geologic work completed at catastrophic rates in the past. One of 400 or so cinder-cone type volcanoes that dot this region, Sunset Crater may be contrasted with the San Francisco Peaks themselves which are the remains of a much larger "composite-cone" (Mount St. Helens-type) volcano. All volcanism in the area must have occurred after the deposition of our flood strata, perhaps at the same time that the great flexures such as the East Kaibab Monocline were forming.

The sunset tints of red and yellow that give the crater its name were probably due to oxidation of the freshly cooled volcanic rocks by hot streaming gases that continued after volcanic activity ceased. Iron oxides, gypsum, and sulfur are some of the minerals found in the area. Tree-ring dating and historical accounts confirm the volcano's eruption to have been in historic times, about the same time William the Conqueror set out for England, in 1065 A.D.

Unfortunately we won't be able to view inside the crater but will instead take a short (40-minute) hike across one of the frozen lava flows and get some feel for the magnitude of volcanic power. Sometime following the lava flows, the volcano belched out great volumes of cinder which are pieces of once molten lava that congealed as they made contact with air and fell literally as a shower of rocks over an area of 120 square miles. Sunset Crater is made out of a loose pile of such cinders that is too unstable to build on. This is why there are no roads to the top.

WALNUT CANYON NATIONAL MONUMENT, ARIZONA
700-1250 A.D. - Culture: Sinaqua

The ruins of approximately 200 small cliff dwellings can be found in the eroded walls of the Toroweap Sandstone. The canyon was named for the stand of Arizona walnut trees found in the bottom of the canyon, and the people who inhabited these apartment houses were the Sinaqua. They came to this area around 700 A.D., and at first lived on top of the canyon in pit houses. Because they had a permanent water supply, an abundance of game and fuel from the nearby forests, life in the canyon was made easier. Besides hunting and gathering, the Sinaqua also grew crops such as corn, beans, and squash. They were skilled in making pottery and basketry, and reached their zenith of cultural development around 1200 A.D. About 1250 A.D., Walnut Canyon was abandoned for unknown reasons, and left untouched for several hundred years.

In the 1880's, the Smithsonian Institution collected some artifacts to take back east and mapped the area. However, shortly after the cliff dwellings were discovered, people came to pot-hunt, and disturbed the ruins. Much destruction took place until 1933, when the ruins were put under the protection of the National Park Service.

METEOR CRATER, ARIZONA

There is an immediate and obvious difference between this type of crater and Sunset Crater, yet both represent enormous amounts of geologic work performed in very short order. Meteor Crater, probably the finest example of such a structure on earth, formed from the prehistoric impact and subsequent explosion of a meteor estimated to have been 80-100 feet in diameter, weighing over 60,000 tons and traveling at 43,000 miles per hour. This rather straightforward interpretation, that a meteor did the work, came to be accepted only with the greatest reticence by the geological establishment, a token of their extreme bias against all forms of catastrophism.

After penetrating some distance into the earth, the meteor exploded, throwing thousands of once molten fragments of meteorite as far as five miles away and throwing the Kaibab Limestone and Coconino Sandstone upward and outward. Because the fragments are of almost pure elemental iron, the meteor is not without economic value, and the underground search by Mr. Barringer makes a very interesting episode in history. Despite the warnings of evolutionary geologists (i.e., anti-catastrophist) and often numerous failed drilling attempts, the main fragment was found buried beneath more than 1,350 feet of sedimentary rock, or well over twice the depth of the present crater! Curiously, ballistics experiments liken Meteor Crater to the pockmark left by a rifle fired into soft mud.

Meteor Crater is 4,200 feet wide, 570 feet deep, could accommodate two dozen Rose Bowls seating 2.5 million people, and was excavated by an explosion equivalent to 1.7 million tons of TNT. The plateau on which Meteor Crater is located is 5,000 feet above sea level.

PETRIFIED FOREST NATIONAL PARK, ARIZONA

The Petrified Forest was never really a forest at all, but a region where tree trunks, in battered condition with limbs and roots broken off and bark stripped away, were rafted in by water and buried quickly beneath volcanic ash and fine-grained sediment. The logs are almost all found resting horizontally. The scenario seems more akin to modern deposits adjacent to Mount St. Helens than the traditional view of sluggish streams and occasional volcanism operating over a period of millions of years. The fossil logs occur throughout the Chinle Formation of the Painted Desert, which owes its varigated color to ash contained within the beds.

Volcanic ash, composed of tiny, puffed-up particles of once molten silica glass, is notorious for its tendency in the presence of water to decompose rapidly to clay. As it does, dissolved silica is released into groundwaters which, when encountering organic material such as the wood of buried tree trunks, gradually replaces the cellulose (wood) in a type of fossilization called silicification. The process need not take long periods of time. For example, approximately 100 miles to the southeast is Fossil Creek which drains a terrain of volcanic rocks and where modern day tree leaves can be found silicified. Thus the rate of silicification can actually exceed the rate of decomposition! Laboratory experiments have also silicified wood rapidly.

Other fossils preserved in these same strata besides the most common conifer trunks include a great variety of plant fossils from fern fronds to leaves of deciduous trees as well as crocodile-like phytosaurs and dragonflies. Although some of the fossil vertebrates are alleged to be amphibian "links" that support the evolutionary transition from water to land, such a vertical succession of fossils has never been found in any one rock sequence and exists only in the fertile imaginations of evolutionists. Those vertebrates which have no modern day representatives can be satisfactorily explained by extinction, a phenomenon (unlike evolution) we can observe today. As for the plants and insects, the fossil forms are very nearly identical to modern ones, and so cannot be their evolutionary "ancestors."

The logs at Petrified Forest are recognized by most geologists to have been deposited in flood conditions. R. C. Moore (Introduction to Historical Geology, McGraw-Hill, 2nd ed., 1958, pp. 401, 402) says:

> There lie thousands of fossilized logs, many of them broken up into short segments, others complete and unbroken...The average diameter of the logs is 3 to 4 feet, and the length 60 to 80 feet. Some logs

7 feet in greatest diameter and 125 feet long have been observed. None are standing in position of growth but, with branches stripped, lie scattered about as though floated by running water until stranded and subsequently buried in the places where they are now found. The original forests may have been scores of miles distant. The cell structure and fibers have been almost perfectly preserved by molecular replacement of silica....

PUERCO RIVER RUIN and AGATE HOUSE
Petrified Forest National Park
1100-1400 A.D. - Culture: Anasazi, Mogollon

The area around the Puerco River was situated between the Anasazi plateau and the Mogollon mountains. It therefore acquired cultural traits from both areas. Within the Park, 109 archeological sites have been located, dating from 300 to 1400 A.D.

Agate House, located at the southern end of the Park, is an eight room pueblo. What makes it truly unique is that it is constructed of chunks of colorful agatized wood.

The Puerco Ruin, located on a bluff south of the Puerco River, contains 125 rooms. Thirty three rooms have been excavated and three kivas discovered. It was arranged in two or three tiers around a central plaza. Points, scrapers, and other tools were made from the petrified wood found locally and flakes can still be found scattered around the ruin. To the east, just below the bluff, numerous Indian petroglyphs are still visible.

ZION NATIONAL PARK, UTAH

Zion canyon, a deep chasm with near vertical walls was first seen by an American in 1825 by fur trapper and part-time evangelist Jedediah Smith. Smith was perhaps the most peculiar of the celebrated "Mountain men," yet was also the most widely respected. In his dealings with the Indians he found particular grace, and has been portrayed with a rifle in one hand and a Bible in the other.

There are a number of geological features here that excite wonder. One may wonder, for example, if the White Cliffs that rise 3500-4000 feet above the valley floor can be explained solely by modern rates of erosion, or do they demand more catastrophic processes? Of course this is a rhetorical question, for we can never know for sure, but we can examine the present processes of erosion to get some perspective. The perenially turbid Virgin River, named after Tom Virgin of the Smith party, can remove up to three million tons of rock per year. Relative to its side tributaries, it has most assuredly downcut, leaving many hanging valleys (e.g., Angel's Landing) and their lovely waterfalls. The road into the park ends at "The Narrows" where the canyon is in places only a few feet wide yet whose walls rise nearly vertically for a remarkable 1500 feet. Tours are led up the narrows in the summer months, but even then the prospects of wading up the icy Virgin River where sunlight shines for but a few brief moments each day is too chilling for most. During flash floods which frequent this region, the river in the narrows has been known to rise 25 feet over a period of just 15 minutes! Who says there's no surfing in Utah!

Another economical process to ponder is spring sapping. Sandstones such as the Navajo Sandstone which forms the steep walls is, despite its very solid appearance, quite porous and is able to conduct water very readily. Beneath the Navajo sandstone at a level just above the valley floor lies shale beds of the Moenave Fm. which in contrast are very poor conductors of water. Now, because the strata tilt ever so slightly (1-2°) to the east, it is along the western wall that the springs tend to occur; the same ones that probably quenched the thirst of Smith's men in 1825. A second implication of this water movement is the loosening of the cement, particularly between the sand grains in the lower part of the Navajo. The effect is to break off the wall in large blocks leaving the western wall with an irregular scalloped outline compared to the relatively straight eastern wall. The water action has a third effect and that is to leach hematite from the upper portions and concentrate it in the lower ones, giving a white over red look to the sandstone walls.

The second enigma to consider while in the park is the origin of the peculiar cross-bedding in the Navajo Sandstone. This is best displayed at Checkerboard Mesa where we will stop. At the visitor center and in most literature 'the experts' are quite sure that, like the Coconino Sandstone in the Grand Canyon, the Navajo represents "fossil" sand dunes accumulated in a vast desert. The alternative view, that these were waterlain deposits (requiring vast currents) was actually beld by many of the first geologists to study the rocks. Were they the product of the Flood, or by slowly migrating sand dunes over the millenia? The facts are all in; the view we choose is largely determined by our presuppositions!

BRYCE CANYON NATIONAL PARK, UTAH

The first people to inhabit this area, as well as that of Zion Canyon were the mysterious Basket Maker Indian culture. They were followed by the Pueblos which in turn were followed by the peaceful Pintes. Ebenezer Bryce, for whom the canyon was named, was a Morman rancher there in the late 1870's. He is said to have held no romance for the area because of the untold frustration he experienced in locating his lost cows among the myriad columns and spires!

Bryce Canyon is not a canyon in the literal sense of the word; it is the very unevenly eroded edge of a plateau that has assumed a bowl-shaped outline. Approximately two to four miles to the east is the Painsagunt Fault from which the 800 foot plateau edge presumably has back-worn from. Because the estimated current erosion on the plateau edge is two feet every 100 years, the uniformitarian geologist reasons that the onset of erosion at the time of fault motion was 700,000 years ago. Can you check his assumptions?

The Pink Cliffs that form the edge of the plateau and the associated erosional forms are composed of the Wasatch Formation. Various systems of joints create the various and sundry arches, windows and bridges. Pinnacles are produced by variations in erosional resistance of the various sandstone, limestone and shale layers that compose the Wasatch. The reddish and brown hues are due to hematite, yellows to limonite, purples to manganese oxide and white where these pigments have been bleached out. The fossils entombed in these rocks include various mammals, plants and invertebrates.

Now is a good time to review regional geology in the context of the Flood. According to the ecological zonation/mobility model as proposed by Whitcomb and Morris in The Genesis Flood one would predict the marine invertebrates to have been buried first, followed in rough order by the amphibians, reptiles, plants and finally mammals. On our field trip we found in the walls of the Grand Canyon (the Paleozoic) predominantly marine invertebrates. The overlying Mesozoic of the Painted Desert, Vermillion Cliffs, etc., were typified by the remains of reptiles and plants. And finally, in the canyon of the Pink Cliffs (Wasatch Fm.) we find the fossilized skeletons of mammals. The model fits at least as well as the evolutionary one does!

MARBLE CANYON NATIONAL MONUMENT, ARIZONA

Prior to the completion of Navajo Bridge in 1928, southern Utah and northernmost Arizona were extremely remote places. This is because the Colorado River was virtually uncrossable for 1000 miles in either direction. There were river crossings, such as Pierce's Ferry beneath present day Lake Mead (at the south end of the Grand Canyon) and one near Hite, Utah 300 miles upstream, but these were far too perilous for most pioneers. Then, in the 1850's, Lee's Crossing (and ferry) was discovered to have been practical, for here the monocline known as Echo Cliffs allowed for passage around the treacherous Triassic cliff-forming strata. The site became famous in 1869 when Major John Wesley Powell and party began their momentous trip down the Colorado River in three small wooden boats. Finally, in 1928, the 616 foot long Navajo Bridge was completed and the west was opened up in a new way.

The bridge abuts on both sides in a very hard, cherty Kaibab Limestone. Within the gorge, the Toroweap and Coconino Sandstones are exposed. It should seem puzzling that the Kaibab Limestone we stand on here is the very same horizon that forms so much of the rim of the Grand Canyon. Note that if the depth of the gorge here is a mere 470 feet while in the Grand Canyon proper it is 5000 feet, then does the river drop 4,500 feet between here and there? No, this is an illusion--otherwise John Wesley Powell would never have survived the waterfalls! The strata have been bent so greatly along the East Kaibab Monocline that the elevation difference of the top of the Kaibab -- between the Grand Canyon and Marble Canyon accounts for the discrepency.

NORTHERN ARIZONA STRATA: A TWO MODEL APPROACH

EVOLUTIONARY MODEL ← DATA → CREATIONIST MODEL

Evolutionary Model

Strata explained by several repeated major transgressions/regressions of the seas, depositing terrestrial, intermediate and marine sediments (as seas of today). Fossils record the evolution of life from inert chemicals to man.

"Age of Mammals/Man"

"Age of Reptiles"

"Age of Amphibians"

"Advance of the Land Plants"

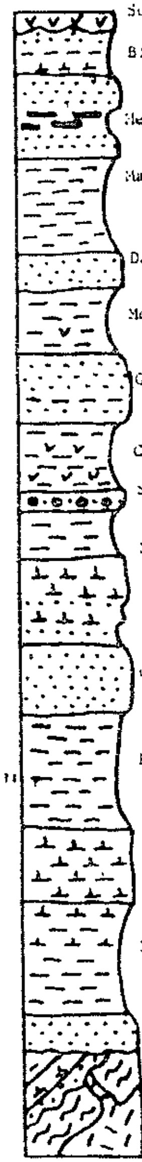
"Age of Fishes"

"Explosion of Life"

"No Life"

4.5 Billion Years Ago

Data



- Sunset Crater Volcanics: Black basalt flows & cinders.
- Bidahochi Fm.: Interbedded light colored sandstone, shale & ash.
- Mesaverde Fm.: Interbedded tan sandstone, grey shale with commercial coal beds.
- Mancos Shale: Soft, monotonous grey shale; contains fossil ammonites.
- Dakota Sandstone: Buff colored, blocky sandstone; forms ledge, produces oil.
- Morrison Fm.: Variegated grey shale with some ash & siltstone. World famous dinosaur skeletons.
- Glen Canyon/San Rafael Groups: Massive, light-colored sandstone w. large-scale crossbeds; interbedded w. occasional reddish shales.
- Chinle Fm.: Variegated grey/violet/red claystone/ash w. fossil logs.
- Shinarump Conglomerate: Greyish chert-pebble conglomerate. Unusual for its wide, blanket-like extent.
- Moenkopi Fm.: Dark reddish brown mudstone.
- Kaibab/Toroweap Fms.: Light grey cherty limestone, sandy in part w. fossil invertebrates.
- Coconino Sandstone: Cream colored sandstone w. large scale cross-beds & quadruped tracks.
- Hermit/Supai Fms.: Distinctive, brick-red mudstone & Sandstone.
- Redwall Limestone: Greyish, cliff-forming limestone, very rich in fossil invertebrates.
- Muav/Bright Angel Fms.: Shaly limestones & limy shales, greyish colored w. fossil trilobites.
- Tapeats Sandstone: Massive greyish-lt. brown sandstone.
- Undifferentiated Basement Rocks: Sedimentary, metamorphic & igneous rocks; very diverse. (detailed descriptions in other parts of text)

Creationist Model

"Post-Flood Rocks"

"Fall of Waters"

"Waters Prevail on Earth"

"Rise of Waters"

"Pre-Flood Rocks"

Several Thousand Years Ago

Strata explained by single, worldwide, year-long flood. All are marine, catastrophic deposits. Rough order of fossils due to hydrodynamic sorting and/or ecological zonation and/or "blooms" of varying marine organisms as flood water geochemistry varied.

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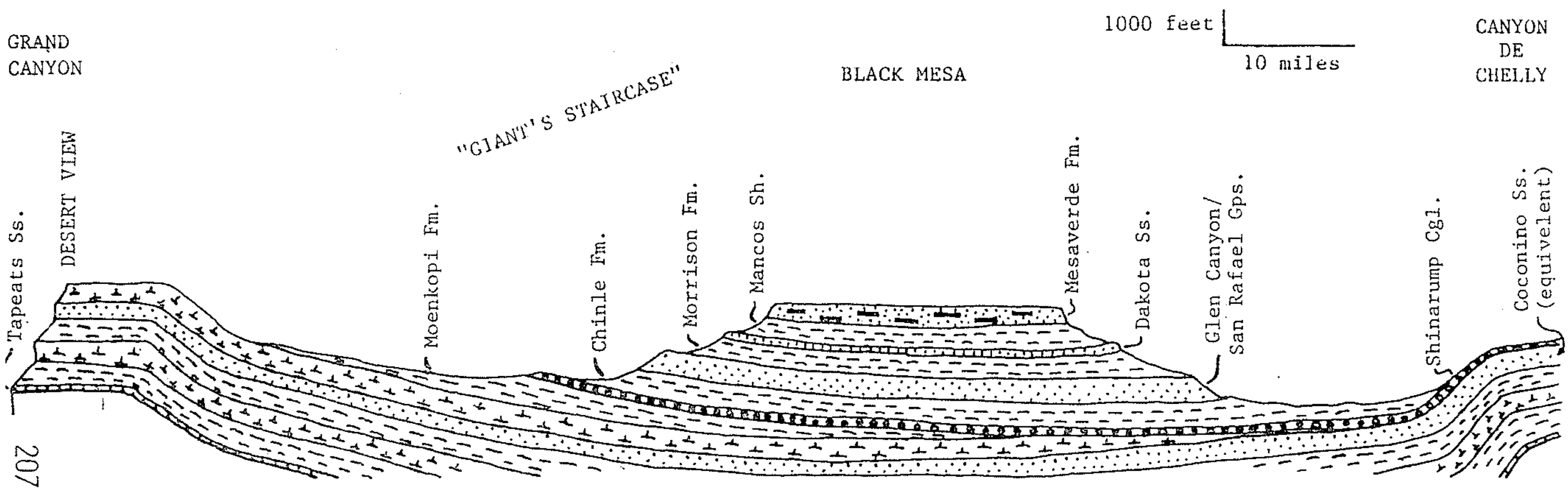
GENERALIZED EAST-WEST CROSS SECTION ACROSS A PART OF NORTHERN ARIZONA



From the Tapeats Sandstone to the Mesaverde Formation the rocks are stacked up in "layer-cake" fashion. Drill hole data has shown that a complete Grand Canyon type section lies preserved beneth Black Mesa, and the Great unconformity is estimated at a depth of approx. 8000 feet. Please note that the vertical scale is highly exaggerated for illustrative purposes. An explanation of the various rock units appears on the following page.

BACKCOUNTRY USE REGULATIONS
GRAND CANYON NATIONAL PARK

1. A Backcountry Use Permit is required for all overnight backcountry use. Your permit MUST be in your possession while in the backcountry. (Your hiking group leader has obtained the permit and will carry it with your group.)

2. No wood or charcoal fires allowed.

3. Carry out your own trash.

4. No firearms or other weapons are allowed.

5. No dogs or other pets are allowed below the rim.

6. Do not cut switchbacks or take shortcuts.

7. Do not throw or roll rocks into the canyon.

8. Do not feed or molest wild animals.

9. Do not dig up, collect or otherwise remove plants, rocks, animals, or other natural or cultural features.

10. Motorized or wheeled vehicles are not allowed below the rim.

11. Fishing by persons 14 years or older requires a valid Arizona fishing license.

12. Do not write on, scratch, or otherwise deface natural features, signs, buildings, or other objects.

13. Private livestock use requires a Backcountry Use Permit.

14. Only one group from an organization may camp in a designated campground or non-corridor use area per night.

EMERGENCY CHECK-IN TELEPHONE NUMBER: (602)638-7888 (24 hours)

BACKCOUNTRY INFORMATION TELEPHONE NUMBER: (602)638-2474

GRAND CANYON DAILY WEATHER (Recording): (602)638-2245

GRAND CANYON FIRST AID ROOM: (602)638-2477

GRAND CANYON CLINIC: (602)638-2551